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PREPARATION OF THIS DOCUMENT

This document has been prepared as part of FAO's Regular Programme activities aimed first at introducing the fisheries forecasting system employed in fishing for coastal pelagic fish around Japan, and second at providing detailed information on global and specific requirements for both the infrastructure and technical backstopping for fisheries forecasting to facilitate the examination of the applicability of such a system in other Member Countries.

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ABSTRACT

The fisheries forecasting system currently employed in Japan has been reviewed from both a technical and administrative point of view. The methodology/technology, data/information and data processing employed, the result and benefits derived have been discussed and appraised in some detail. The system contribution to the total Japanese fisheries production and the socio-economic benefits to the nation have also been discussed. The linkage between forecasting and the fisheries management scheme employed in Japan has been examined. Finally, a review of general requirements for and guidelines on, the establishment of a fisheries forecasting system in other countries have been given.

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1. INTRODUCTION

The roles of the various environmental factors played in the success or failure of fishing operations, resources research and management have been discussed in many papers (e.g. Laevatsu and Hela, 1970, Tomczak, 1977). Fisheries forecasting is one application of these natural rules to fishing industries.

Among these factors, oceanographic conditions are most closely linked to fish resources and fisheries. These conditions can be put into two different categories, according to their short- and long-term implications. The methods and techniques to be employed in fisheries forecasting differ greatly by category.

In the short-term for instance, changes in some oceanographic conditions in a specific water would immediately affect the behaviour of the fish there. These include changes in water temperature, salinity, sea currents and the distribution pattern of a specific watermass, etc., which easily affect the migration, displacement and distribution range of fish or the density and size of fish schools. Once these behavioural changes occur in fish, fisheries are greatly affected through changes in fishing ground, season and/or catchability. These phenomena generally occur within a relatively short period, sometimes within a few days, and a few months, in the other.

Short-term fisheries forecasting therefore aims to predict the changes that are most likely to take place in target fish in the immediate future. Thus, short-term forecasts are always issued together with the latest oceanographic information and catch data. Promptness and timeliness are the most vital requirements in this sector.

Long-term forecasting, on the other hand, involves quite different concepts and procedures from those mentioned above and requires more biological and oceanographic information. The long-term effects of a change in oceanographic conditions sometimes result in a change in the abundance of fish stocks through success or failure in spawning, changes in survival rates during early life stages and, subsequently, in recruitment size. These ultimately result in changes in catchability and total fisheries production. Forecasting such long-term changes is very important not only for fishermen but also for the administrators in planning fisheries management and/or national food and industrial policies. Long-term fisheries forecasting is thus more academic and managerial than short-term forecasting.

In Japan, short-term forecasting has been practically implemented by the Japan Fisheries Information Service Center (JFIC)[1], a subsidiary organization of the central government, in collaboration with national and local fisheries research institutes. Long-term forecasting, on the other hand, is carried out chiefly by the oceanographic and resources departments of the national fisheries research institutes in close collaboration with local fisheries experimental stations of the prefectural governments, over the entire coast of Japan.

The authors present in this paper a review of the fisheries forecasting system currently employed in the coastal pelagic fish fisheries in Japan from both a technical and administrative point of view. The methodology/technology, data/information and data processing employed, and the results and benefits derived are discussed and appraised in some detail in the following sections. The role of the system played in Japanese fisheries production and the socio-economic benefits for the nation are also discussed. The linkage between forecasting and the fisheries management scheme employed in Japan is also examined. Finally, a global review of general requirements for/and a guide-line on, the applicability of a fisheries forecasting system in other countries are given.

2. INFRASTRUCTURE, ACTIVITIES AND FUNCTIONS

2.1 Historical Review

In Japan, the establishment of the theoretical basis for fisheries forecasting, in conjunction with oceanography, can be traced back to a long time ago. A clear hypothesis was proposed in the early twentieth century on the relationship between the behaviour of fish and various oceanographic conditions, especially those in conjunction with the formation and the variation of water fronts (Fisheries Training Institute of Japan, 1918, Kitahara 1922). This was the first published statement that became the scientific basis of the fisheries forecasting service in Japan, although Japanese fishermen had already been well aware of, by their sixth sense, the principle that "the water fornt, where two different sea currents converge, gathers fish". This hypothesis, called the "Kitahara's Law" thereafter in Japan, after the pioneer and has been studied and developed by a

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number of successors in this field (e.g., Uda[1], Kimura[2], Nakai, 1962[3], Tsujita[2], etc.). It has now become a well established theory in Japanese marine biology. The various studies carried out so far on the relationship between the oceanographic environment and living resources have been reviewed and well documented by Nasu (1975) from a global point of view, covering all the oceans of the world.

In accordance with the above mentioned development, a nationwide oceanographic survey covering a wide area was initiated in Japan in the early 1930's. The survey was carried out chiefly by the Imperial Fisheries Experimental Station, in close collaboration with various prefectural fisheries experimental stations. The research vessels of these stations were used to observe the sea, and these were supplemented by a number of selected fishing vessels, which assisted the survey by reporting data on surface water temperature and catch during their fishing operations. Lighthouses all over the Japanese coast also assisted the survey by reporting their regularly collected data on water temperature and specific gravity. In addition, the major wholesale fish markets regularly reported the statistics on landings.

In the mid-1930's a regular fisheries forecasting service was started by the government. The national radio broadcasting service (Japan Broadcasting Corporation or "Nihon Hoso Kyokai" in Japanese), was first used to disseminate the information. The fisheries forecast was broadcasted once a week as part of the regular daily news report. However, this was unfortunately interrupted in 1941 by the outbreak of the Second World War.

After the war, fisheries forecasting activity was gradually resumed, first on a local basis, in accordance with the overall recovery in national economy, welfare and industries, especially with the reorganization and reinforcement of the fisheries research institutes at both national and local levels.

For example, the collection of the data on water temperature was resumed at an early stage of the recovery, covering skipjack and saury fishing in offshore waters of the northeastern Pacific coast. The data, collected mostly from fishing vessels, were regularly compiled, processed and printed as water-temperature maps of the fishing grounds and distributed to the fishermen concerned.

The Cooperative Oceanographic Survey for the sardine fishery was resumed in the Japan Sea by research vessels from the local institutes along the coast. The survey was technically coordinated by a national fisheries research institute responsible for the region, the Japan Sea Regional Fisheries Research Laboratory, and consisted of simultaneous observations covering a fairly wide area of the Sea beyond the boundaries of local governments.

In the mid-1950's, the Fishing Ground Information Extension Association (FGIEA) was established, aiming chiefly at facilitating fishing for skipjack tuna and Pacific saury along the northeastern Pacific coast of Japan. The FGIEA was a non-governmental organization but was supported by a national institute in the region, Tohoku Regional Fisheries Research Laboratory. These two organizations cooperated with each other to provide fisheries forecasting. The FGIEA played the role of data collector and forecasts disseminator in the system, while the research institute fully backstopped the technical aspects of the forecasting. It is noted that a radio was first used in the system as a means of communication network between the FGIEA and fishing vessels in addition to mail service. These were the origins of the current system employed by the Japan Fisheries Information Service Center (JFIC).

In the winter of 1963/64, unusually low temperatures prevailed over the coastal waters around Japan, which coincided with the worst period for sardine production on record. The annual catch, about 2.7 million tonnes during the mid-1930's, fell to only about 9 000 tonnes. A sudden overall decrease in the production of other fish took place during the same period. Under these circumstances a nationwide fisheries forecasting system was re-established by the government.

In 1964 the Fishing and Oceanographic Conditions Forecasting Project, a national project funded by the central government started, aiming at forecasting the catchability of major coastal pelagic fish stocks around Japan. These include Japanese sardine, Japanese anchovy, Japanese chub mackerel (common mackerel), Japanese Jack mackerel, Pacific saury, skipjack tuna (only those that had migrated into Japanese waters) and Japanese flying squid. The infrastructure of the project comprised, (i) the Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, as the administrative body, (ii) the national fisheries research institutes as the core in the technical fields and (iii) the prefectural fisheries experimental stations as cooperative bodies.

---

[1] Numerous contributions on the subject were made during 1939 to 1981 (Watanabe et al., 1969).

[2] A great number of papers on the subject have been published, mostly during the 1950's and 80's.

[3] A number of papers on the subject have been published in addition to the paper referred to in this paper.

Following the commencement of the national project mentioned above, the Fisheries and Oceanographic Information Center was established in 1965, under the auspices of the National Federation of Fisheries Cooperatives, aiming at cooperating with the national fisheries forecasting project, in particular to facilitate the dissemination of forecasts to fishermen.

After successful improvements in this activity, the Center was strengthened in 1972 and transformed into the Japan Fisheries Information Service Center (JFIC), a government subsidiary institute. Now the Center plays an important role as the information service agency in the entire forecasting system. It has been extremely effective, particularly in handling laborious data collection, processing and timely dissemination of the forecasts.

2.2 Activities

The fisheries forecasting activities currently employed in Japan comprise three main functions, namely, the (i) long-term forecast (ii) short-term forecast and (iii) information service. The term "long-term" referred to implies, in most cases, two to three months ahead and, in some cases, much longer.

Figure 1 shows a schematic illustration of the infrastructure of the fisheries forecasting system employed in Japan and the data/information flow among the institutes and parties involved.

2.2.1 Long-term forecast

This is to provide the medium - to long-term projection of probable changes or stability in the oceanographic and fishing conditions for major coastal pelagic fish stocks around Japan. This aims to assist in planning the medium - to long-term (i) fishing operations for fishermen and fisheries entrepreneurs, (ii) fisheries coordination and management for the administrators, and (iii) research for the fisheries research institutes during the forthcoming fishing season. However, the benefits and beneficiaries, in a broader sense, are distributed through various sectors of the nation which will be discussed later (see section 7 ,"Discussion").

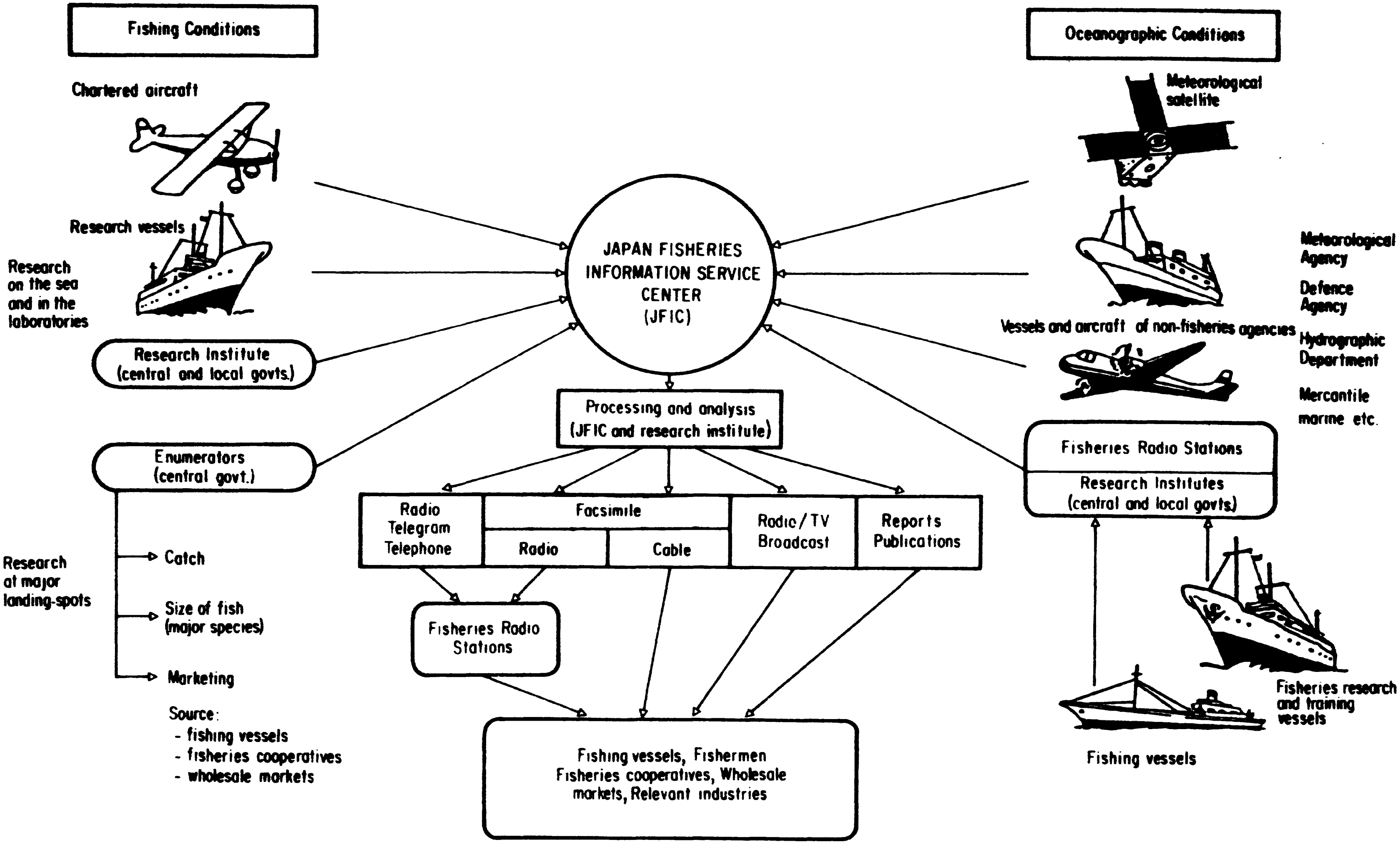
The regional fisheries research institutes of the central government are chiefly responsible for the long-term forecast, in close collaboration with the fisheries experimental stations of the local governments concerned. As part of their Regular Programmes these institutes have carried out, for some time now, various studies on the relationships between the oceanographic and fishing conditions for major coastal fish resources, on a global and regional basis (national institutes) and on a local basis (prefectural institutes).

Newly collected data/information are immediately processed and analysed by each of the institutes, based on knowledge accumulated in the past. Then regional/technical meeting, both informal and semi-formal, are held frequently to bring together and to discuss the results obtained in each of the institutes through the exercises mentioned above. The Japan Fisheries Information Service Center (JFIC) also takes part in these meetings as a major participant. Thus a preliminary consolidated draft forecast is made for each of the stocks and regions.

The draft forecast to be officially approved for each region is then prepared by each of the national institutes responsible for that region, taking into account the results of the above mentioned discussions. Table 1 shows how species and areas of responsibility are shared by the national fisheries research institutes. The draft forecast includes substantial explanatory text and figures on projected trends in oceanographic and fishing conditions for the following few months. The important items to be covered are the (i) fishing season, (ii) fishing grounds and their changes, (iii) density, (iv) abundance and (v) catchability of the exploitable fish stocks.

The Fishing and Oceanographic Conditions Forecasting Conference has been established to examine and approve the draft forecast prepared. The meetings are organized several times a year, usually on a regional basis. The research institutes in the region (both national and prefectural) and the JFIC all participate. After agreement on the draft, the conference approves a forecast to meet the demand for forecasting the important target fish species in the region. For some fish species that are distributed or migrate beyond the border(s) of a region(s), joint meetings of the two or more regional Conferences are held, when necessary, to cover wider waters, e.g., skipjack tuna, Japanese flying squid and Pacific saury, etc.

The forecast, once approved and authorised by the Conference, is immediately transmitted to the Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries for release to the public. The forecast then goes to the press and is distributed widely to the national and local research institutes, the JFIC and other relevant organizations. The mass-media, including newspapers, radio and TV broadcasting are also used to convey the forecast to the public.


Fishing Conditions
Chartered aircraft
Research vessels
Research on the sea and in the laboratories
Research Institute (central and local govts.)
Enumerators (central govt.)
Research at major landing-spots
Catch
Size of fish (major species)
Marketing
Source:
- fishing vessels
- fisheries cooperatives
- wholesale markets
JAPAN FISHERIES INFORMATION SERVICE CENTER (JFIC)
Processing and analysis (JFIC and research institute)
Radio Telegram Telephone
Facsimile
Radio
Cable
Radio/TV Broadcast
Reports Publications
Fisheries Radio Stations
Fishing vessels, Fishermen Fisheries cooperatives, Wholesale markets, Relevant industries
Oceanographic Conditions
Meteorological satellite
Vessels and aircraft of non-fisheries agencies
Meteorological Agency
Defence Agency
Hydrographic Department
Mercantile marine etc.
Fisheries Radio Stations
Research Institutes (central and local govts.)
Fisheries research and training vessels
Fishing vessels

.gure Schematic illustration of infrastructure and da curren emp yed in he fisheries forecas ng ystem in Japan.

Table 1

Share of the species and region wise responsibilities of fisheries forecasting among the national fisheries research institutes[1/].

Species	Region	National Institute
Japanese sardine, Japanese anchovy, Japanese chub mackerel, Japanese Jack mackerel	North to central Pacific region (Hokkaido-Tohoku-Tokai regions)[2/]	Tokai Regional Fisheries Research Laboratory, Tokyo
	Nansei region[3/]	Nansei Regional Fisheries Research Laboratory, Hiroshima and Kochi
	Seikai region[4/]	Seikai Regional Fisheries Research Laboratory, Nagasaki
	Japan Sea region[5/]	Japan Sea Regional Fisheries Research Laboratory, Niigata
Japanese amberjack (yellowtail)	Nansei region[3/]	Nansei Regional Fisheries Research Laboratory, Hiroshima
	Japan Sea region[5/]	Japan Sea Regional Fisheries Research Laboratory, Niigata
Pacific saury, skipjack tuna	Tohoku region[6/]	Tohoku Regional Fisheries Research Laboratory, Shiogama
Japanese flying squid	Hokkaido region[7/] plus northeast Pacific coast	Hokkaido Regional Fisheries Research Laboratory, Kushiro
	Japan Sea region[5/]	Japan Sea Regional Fisheries Research Laboratory, Niigata

[1/] Forecastings are jointly made by two or more institutes for the stocks straddling over two or more regions.

[2/] Pacific coast of the Hokkaido, the northernmost large island of Japan, to the southern central Pacific coast of the Honshu, the central main island of Japan, through the north and central Pacific coasts of the Honshu.

[3/] Southwestern Pacific coast of Japan, including the Seto Inland Sea.

[4/] Eastern East China Sea, including the Korea Strait between Japan and the Korean Peninsula.

[5/] Entire Japan Sea.

[6/] Northeastern Pacific coast of the Honshu, central main island of Japan.

[7/] Waters around the Hokkaido, the northernmost large island of Japan, including the parts of the Pacific Ocean, the Okhotsk Sea and the Japan Sea.

2.2.2 Short-term forecast

This is to provide, as quickly as possible, the latest information on oceanographic and fishing conditions and the short-term projection on any changes or their stability likely in the immediate future for major coastal fish stocks around Japan. The forecasts greatly assist the (i) fishermen and fishing entrepreneurs to fish effectively and (ii) research institutes and fisheries administrations in monitoring continuously the (a) oceanographic conditions, (b) state of the stocks and (c) fishing operations. This contributes to better resources and fisheries management. As with long-term forecasting, the entire beneficiaries are not only those mentioned above but are spread much further (see section 7).

The JFIC plays the most important role in this activity. It is extremely effective in collecting and processing data rapidly and in arranging quickly the prompt dissemination of the forecasts. The forecast is usually disseminated in two ways: (i) by the mass media and (ii) through its own Prompt Reports[1/]. The Report is usually issued at three- to ten-day intervals and mailed to members of the JFIC, including individual fishermen, fisheries entrepreneurs, various fisheries cooperatives, wholesale markets, processors, etc. The members can thus receive the latest forecast within five to ten days timelag to real-time.

Members who have installed a telecommunication system (facsimile by cable or radio) on their premises receive the information more promptly. Members who are at sea (crusing or fishing on vessels) receive the substantive contents of the Prompt Report by radio or radio-facsimile through the Japan Fisheries Radio Station network (see section 2.6 and Figure 1).

The JFIC's installation of modern technology and equipment has greatly facilitated the quick handling of the data and the prompt dissemination of the forecasts. For instance, the computerized data processing system of the Center can draw a seawater temperature map on the same day of the arrival of the latest data, which has also been quickened by the installation of the telecomunication system at the Center. Another example is the installation of a satellite imagery analyser, which has enabled the Center first to upgrade greatly the overall accuracy and secondly to speed up the forecasting process. However, it should be emphasized here that these improvements in the technical capability of the JFIC have been made possible as a result of the full support and backstopping given by the research institutes, both central and local, and by the scientists concerned from various fields.

2.3 Budgetary Basis

It is almost impossible to estimate accurately the expenditure exclusively directed to forecasting. This is because many of the basic activities necessary for forecasting are covered by the Regular Programmes of the government institutes at both central and local levels. The cost of fisheries forecasting activities, especially regarding research and studies on the waters and on the fish stocks in question, are inseparable from the total figure of the institution's budgets, since such research is undertaken as part of their Regular Programme activities. The forecasting would never have been carried out without these contributions.

In these circumstances, a global budgetary basis of the central government shown in Table 2, may give only a rough idea of how expensive the forecasting service is.

The JFIC runs on both a subsidy granted by the central government and its own income. The income comprises (i) membership fees[1/] and (ii) earnings from selling its Prompt Forecast Reports other information and various publications. The annual income usually accounts for about 35 percent of the total budget of the Center. However, since it is a public service corporation subsidized by the central government, no profits are allowed to be retained by the Center.

2.4 Data Collection by Central and Local Institutes

The data and information collected systematically are composed of three major items: (i) catch statistics, which include basic biological parameters, (ii) information on spawning and early survival of the target stock, and (iii) oceanographic data. Figure 2 illustrates schematically the collection of these data/information and the way they flow in through the system.

2.4.1 Statistics: catch and basic biological parameters

(1) Catch statistics

The Statistics and Information Department of the Ministry of Agriculture, Forestry and Fisheries (SID.MAFF) is responsible for compiling these statistics. Submission of the daily

---

[1/] Report on Fishing and Oceanographic Information - "Gyokaikyo Sokuho" in Japanese, see Figures 4-A and 4-B for an example.

Table 2

Global budgetary basis of the central government for the coastal pelagic fish fisheries forecasting system in Japan.
Figures refered are those for the 1986 fiscal year (April 1986 to March 1987).

(million yen)

Budgetary item (activities)	Recipient bodies			Total
	National institutes	Prefectural governments	Japan Fisheries Information Service Center (JFIC)	
(1) Fishery resources research in 200 miles Exclusive Fishing Zone	775[1]	419[2]	-	1 194
(2) Research vessel cruise cost	256[1]	[3]	-	256
(3) Fishing and oceanographic conditions forecasting project[4]	[4]	74[5]	-	74
(4) Fishing and oceanographic conditions information service[6] project	-	-	90[6]	90
Total	1 031	493	90	1 614

---

[1] Includes all the Regular Programme activities on resources research and assessment.

[2] Only subsidy to the local governments concerned. The lump sum amount of the budget at local level for their Regular Programme activities is far greater than the subsidy.

[3] Information not available. This would be far greater than the national budget, as a number of prefectural research vessels being involved.

[4] This is only for the subsidiary fund for local governments. The cost at national level is covered by the items (1) and (2).

[5] The contribution of the same amount of funds is mandatory for the local governments.

[6] This is only for the JFIC. The JFIC has its own income budget, which was 47 million yen in 1986. The total running cost of the year was, therefore, 137 million yen (see text for details).

catch record in defined format is mandatory for all licensed fisheries. The format of the report differs according to the licensing and granting category of the fishery. It has been standardized on a national basis for the large-scale fisheries and a prefectural basis for the small-scale fisheries[2/]. The reports are collected by branch offices of the SID.MAFF deployed in each of the prefectures, through fisheries cooperatives at landing point and the Fisheries Division of the Prefectural Government, which supervises the local wholesale markets. The preliminary processed data by the SID.MAFF branch offices are transmitted to the central office of SID.MAFF, Tokyo, then processed into final format, printed and distributed all over the country. In the meantime, the interim results of the catch statistics at various levels (i.e., landing point, prefectural government and branch office of SID.MAFF) are made available to the regional fisheries research institutes and the local fisheries experimental stations to be used for the implementation of their Regular Programme activities, which include fisheries forecasting.

(2) Basic biological parameters

Periodic measurements of the frequency distribution of fish size, sex ratio and maturity, etc. of the catch are carried out by SID.MAFF for important fish species at selected major local landing points. The SID.MAFF has 85 enumerators deployed at 82 landing points over the Japanese coast for this purpose. The flow of these data and their availability to central and local institutes for forecasting purposes are completely the same as those for the catch statistics mentioned in the previous sub section.

2.4.2 Spawning and early survival

Information on spawning and early survival of fish is vital not only for stock assessment but also for forecasting purpose. The spawning survey has been carried out largely by the national fisheries research laboratories, as it is highly technical (in terms of tools and technology employed on board and identification of eggs and larvae in the laboratory) and costly (in terms of research vessels and their running costs, equipment, wide areas to be covered, sample storage and processing, etc.).

The following example of the spawning survey of Japanese sardine illustrates well the magnitude of this type of survey and the value of the information obtained. The three regional fisheries research institutes (the Tokai, Nansei and Seikai Regional Fisheries Research Laboratories) undertake a joint spawning survey every year covering a wide area from the northeastern to the southwestern Japanese coast. The samples are collected from 1 000 stations, which are deployed on a grid frame over the survey area. The vertical (150-0 m) and horizontal hauling of both standardized larva-nets and plankton-nets are performed at each station, which produces at least 2 000 samples to be examined by the human eye within a short time. As a result, the magnitude of, and time-spatial change in, the spawning in that specific year can be assessed by examining this easily interpreted material. This is very important information on forecasting for the forthcoming fishing season for both juvenile and adult fish as spawning magnitude indicates clearly not only the potential magnitude of recruitment but also the abundance of existing parental fish. Further detailed quantitative estimates on the data collected are made for long-term forecasting and assessment/management purposes for all stocks and fisheries (see, section 5.3 and Figure 24).

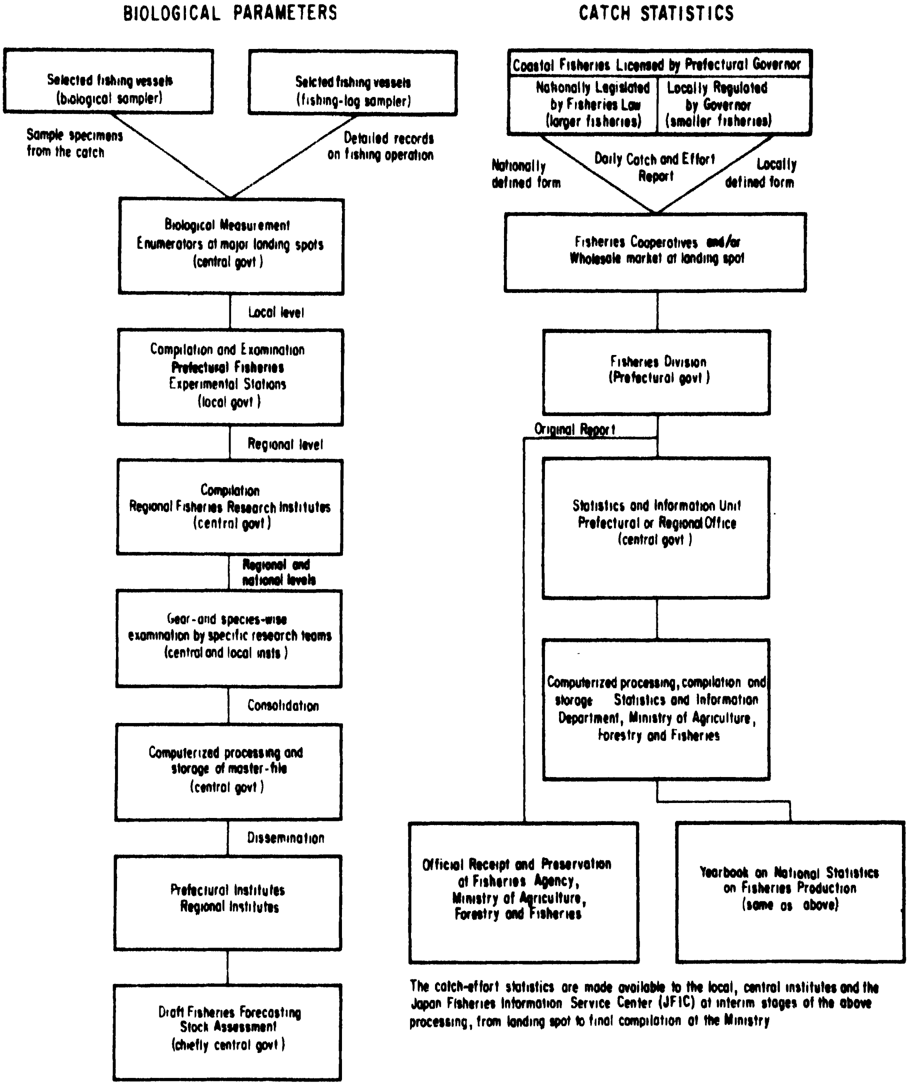
2.4.3 Oceanographic data

As one of the Regular Programme activities more than 2 000 stations covering all the coastal waters around Japan, have been deployed to collect basic oceanographic information continuously every year. The location of these stations has been fixed over the years so as to assure the compatibility of the time series data. Figure 3 shows the courses to be followed in this survey by the assigned research vessels. This survey has been undertaken mostly by the local fisheries experimental station. The central government, however, reimburses 50 percent of the running costs. (See, section 2.3 and Table 2).

The national fisheries research laboratories also conduct their own Regular Programme oceanographic survey every year in each of the responsible regions. Eleven research vessels from six laboratories are used and a total of about 2 000 stations are covered.

1/ The members are (i) 31 prefectural governments bordering the sea, (ii) National Federation of Fisheries Cooperatives, (iii) 6 national federations of fisheries cooperatives for major pelagic fish fisheries, (iv) various fisheries cooperatives at various levels and (v) individual fishermen, fishing entrepreneurs and relevant industries.

2/ See section 7.3.1 item (1) and Table 12 for the licensing/granting scheme of the relevant fisheries.


BIOLOGICAL PARAMETERS
Selected fishing vessels (biological sampler)
Selected fishing vessels (fishing-log sampler)
Sample specimens from the catch
Detailed records on fishing operation
Biological Measurement Enumerators at major landing spots (central govt)
Local level
Compilation and Examination Prefectural Fisheries Experimental Stations (local govt)
Regional level
Compilation Regional Fisheries Research Institutes (central govt)
Regional and national levels
Gear-and species-wise examination by specific research teams (central and local insts)
Consolidation
Computerized processing and storage of master-file (central govt)
Dissemination
Prefectural Institutes Regional Institutes
Draft Fisheries Forecasting Stock Assessment (chiefly central govt)
CATCH STATISTICS
Coastal Fisheries Licensed by Prefectural Governor
Nationally Legislated by Fisheries Law (larger fisheries)
Locally Regulated by Governor (smaller fisheries)
Nationally defined form
Daily Catch and Effort Report
Locally defined form
Fisheries Cooperatives and/or Wholesale market at landing spot
Fisheries Division (Prefectural govt)
Original Report
Statistics and Information Unit Prefectural or Regional Office (central govt)
Computerized processing, compilation and storage Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries
Official Receipt and Preservation at Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries
Yearbook on National Statistics on Fisheries Production (same as above)

The catch-effort statistics are made available to the local, central institutes and the Japan Fisheries Information Service Center (JFIC) at interim stages of the above processing, from landing spot to final compilation at the Ministry

Figure 2 Schematic illustration of the collection of data and their flow for the purpose of fisheries forecasting.

The data collected by these surveys are reported daily to the Fisheries Agency, the regional fisheries research laboratory and the JFIC by radio, facsimile, etc. These are immediately processed and used by the JFIC for short-term forecasting.

2.5 Data Collection and Processing by the Japan Fisheries Information Service Center (JFIC)

2.5.1 Oceanographic data

This refers to the data collected by the JFIC on its own, which are different from those collected by the systematic process described in the previous sub section. The data source comprises (i) fishing vessels, (ii) training vessels of fisheries high schools, (iii) fisheries cooperatives, (iv) inspection vessels of the Maritime Safety Agency, Ministry of Transportation (MSA.MT), and (v) the mercantile marine. The data from the first two are sent mostly by radio through the Japan Fisheries Radio Station network and partly by a facsimile network through fisheries cooperatives. A special telephone link has been established between the JFIC and the MSA.MT, which transmits the data reported by the inspection vessels and the mercantile marine.

The data on surface water temperature (SST) are processed regularly and periodically by a computerized system that plots out the results on a chart as previously mentioned. The isotherms

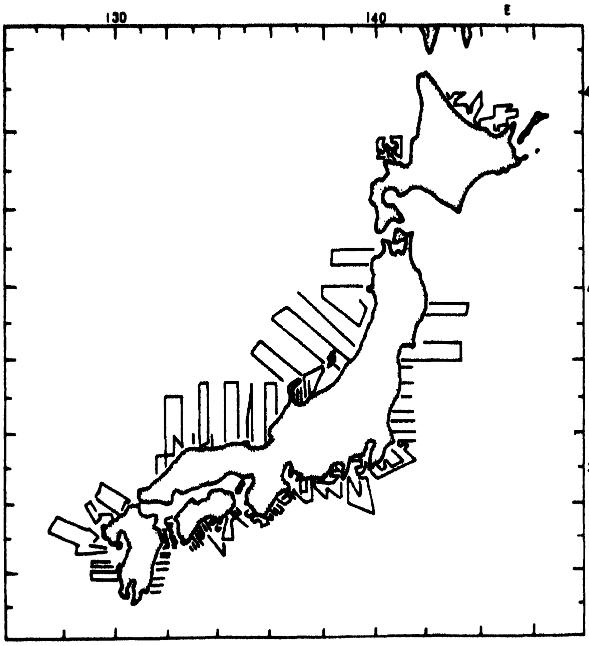


Figure 3 Cruise routes followed in oceanographic observations in coastal waters around Japan, carried out chiefly by research vessels from local institutes.

are, at present, hand drawn by experienced professionals, but trials are now being undertaken to develop a computer drawing system. The draft isotherm map is then printed together with information on other oceanographic and fishing conditions. This includes the latest information on sea currents and current-rip water fronts, etc. This is the major flow of how the "Prompt Report" is prepared (see the following section to see how it is disseminated). The total number of SST data used in the Prompt Report amounts to about 350 000 every year.

In addition to the digital data mentioned above, the JFIC collects analogical and visual data by aerial survey with chartered air crafts. The aerial survey is carried out several times a year, aiming at collecting information on surface water temperatures by infra-red photography, and rip currents, water fronts and fish schools by sighting.

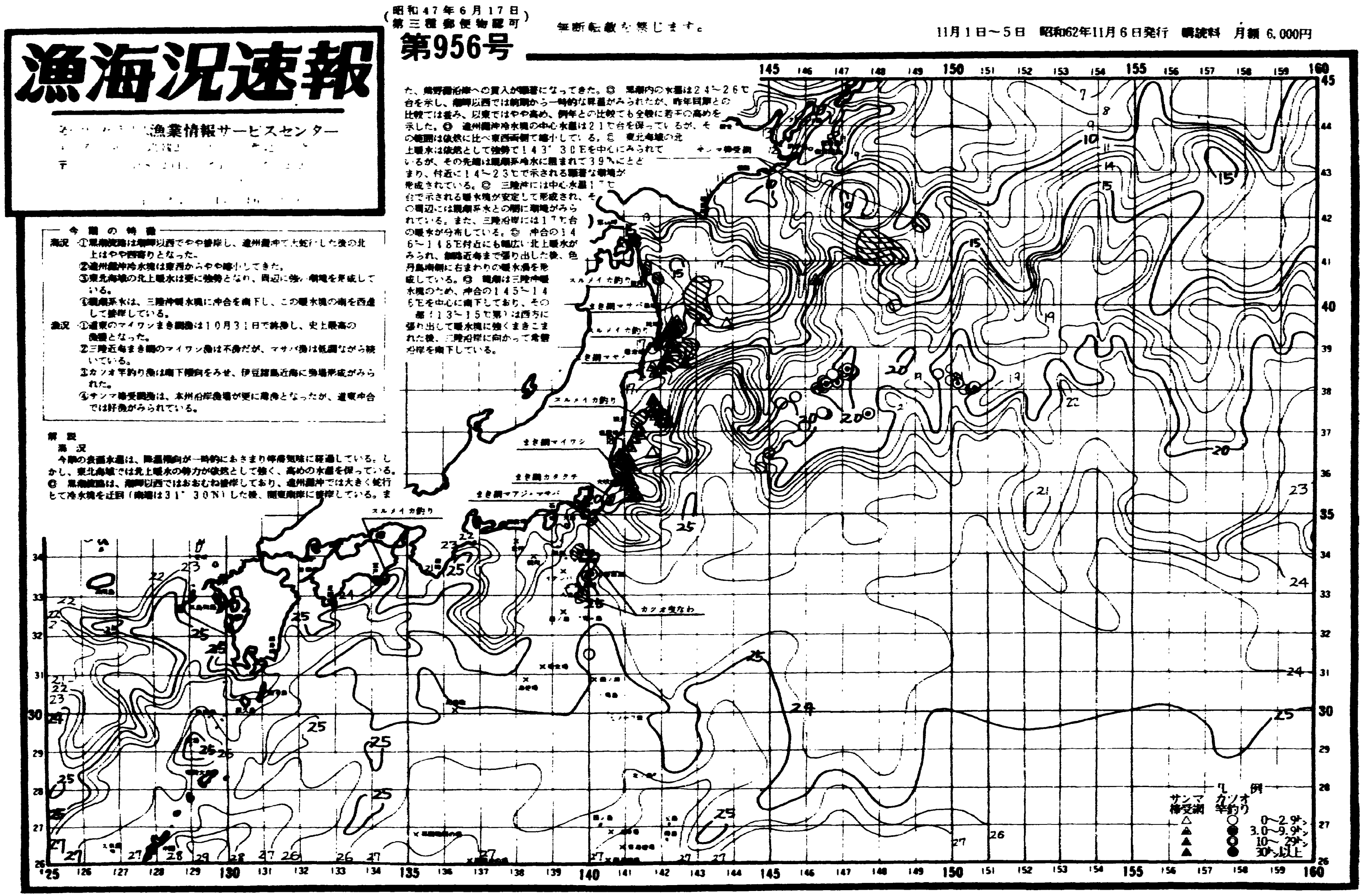
2.5.2 Fishing conditions

A number of JFIC enumerators (about 140) have been deployed at major landing points (22 in total) along the entire coast to collect various information regularly from selected fishing vessels. This includes data on fishing grounds, fishing effort employed, catches in particular grounds and sighting of fish schools, etc. The catch rates in specific fishing grounds calculated from these data are also incorporated into the short-term forecast and are displayed in the Prompt Report. An example is shown in Figures 4-A and 4-B.

2.5.3 Satellite imagery

In 1985 the JFIC started, after several years of preparatory experiments, an operation on remote sensing by means of satellite imagery of the sea. The infra-red signal of the Advanced Very High Resolution Radiometer (AVHRR) of the NOAA No. 9 satellite is received at the Japan Meteorological Satellite Center, Meteorological Agency, Ministry of Transportation (JMSC.MT), which is located in a northern suburb of Tokyo.

A copy of the received and saved data of AVHRR at JMSC.MT is delivered to the JFIC daily and is processed immediately to print out sea-water-temperature photographs for the waters/regions concerned. The JFIC's processor modifies the original imagery to make up a picture that can be transmitted by facsimile. The original photographs are interpreted to produce (by hand) two types of map: (i) an isotherm map and (ii) a current-pattern map that includes schematic illustrations of rips currents, water fronts and eddies, etc. These three maps (original isotherm and current maps)



（昭和47年6月17日
第三種郵便物認可）

無断転載を禁じます。

11月1日～5日 昭和62年11月6日発行 購読料 月額 6,000円

漁海況速報

漁業情報サービスセンター

第956号

今期の特徴

海況 ①黒潮流路は潮岬以西でやや接岸し、遠州灘沖で大蛇行した後の北上はやや西寄りとなった。

②遠州灘沖冷水塊は東西からやや縮小してきた。

③東北海域の北上暖水は更に強勢となり、周辺に強い潮境を形成している。

④親潮系水は、三陸沖暖水塊に沖合を南下し、この暖水塊の南を西進して接岸している。

漁況 ①道東のマイワシまき網漁は10月31日で終漁し、史上最高の漁獲となった。

②三陸近海まき網のマイワシ漁は不漁だが、マサバ漁は低調ながら続いている。

③カツオ竿釣り漁は南下傾向をみせ、伊豆諸島近海に漁場形成がみられた。

④サンマ棒受網漁は、本州沿岸漁場が更に離岸となったが、道東沖合では好漁がみられている。

解説

海況

今期の表面水温は、降温傾向が一時的におさまり停滞気味に経過している。しかし、東北海域では北上暖水の勢力が依然として強く、高めの水温を保っている。◎ 黒潮流路は、潮岬以西ではおおむね接岸しており、遠州灘沖では大きく蛇行して冷水塊を迂回（南端は31°30′N）した後、関東南岸に接岸している。また、熊野灘沿岸への貫入が顕著になってきた。◎ 黒潮内の水温は24～26℃台を示し、潮岬以西では前期から一時的な昇温がみられたが、昨年同期との比較では並み、以東ではやや高め、例年との比較でも全般に若干の高めを示した。◎ 遠州灘沖冷水塊の中心水温は21℃台を保っているが、その範囲は依然に比べ東西両側で縮小している。◎ 東北海域の北上暖水は依然として強勢で143°30′Eを中心にみられているが、その先端は親潮系冷水に阻まれて39°Nにとどまり、付近に14～23℃で示される顕著な潮境が形成されている。◎ 三陸沖には中心水温17℃台で示される暖水塊が安定して形成され、その周辺には親潮系水との間に潮境がみられている。また、三陸沿岸には17℃台の暖水が分布している。◎ 沖合の146～148°E付近にも幅広い北上暖水がみられ、釧路近海まで張り出した後、色丹島南側に右まわりの暖水渦を形成している。◎ 親潮は三陸沖暖水塊のため、沖合の145～146°Eを中心に南下しており、その一部（13～15℃系）は西方に張り出して暖水塊に強くまきこまれた後、三陸沿岸に向かって常磐沿岸を南下している。

Figure 4-A An ex he Pr Repor sh es orecas coas wa around apan
(fron

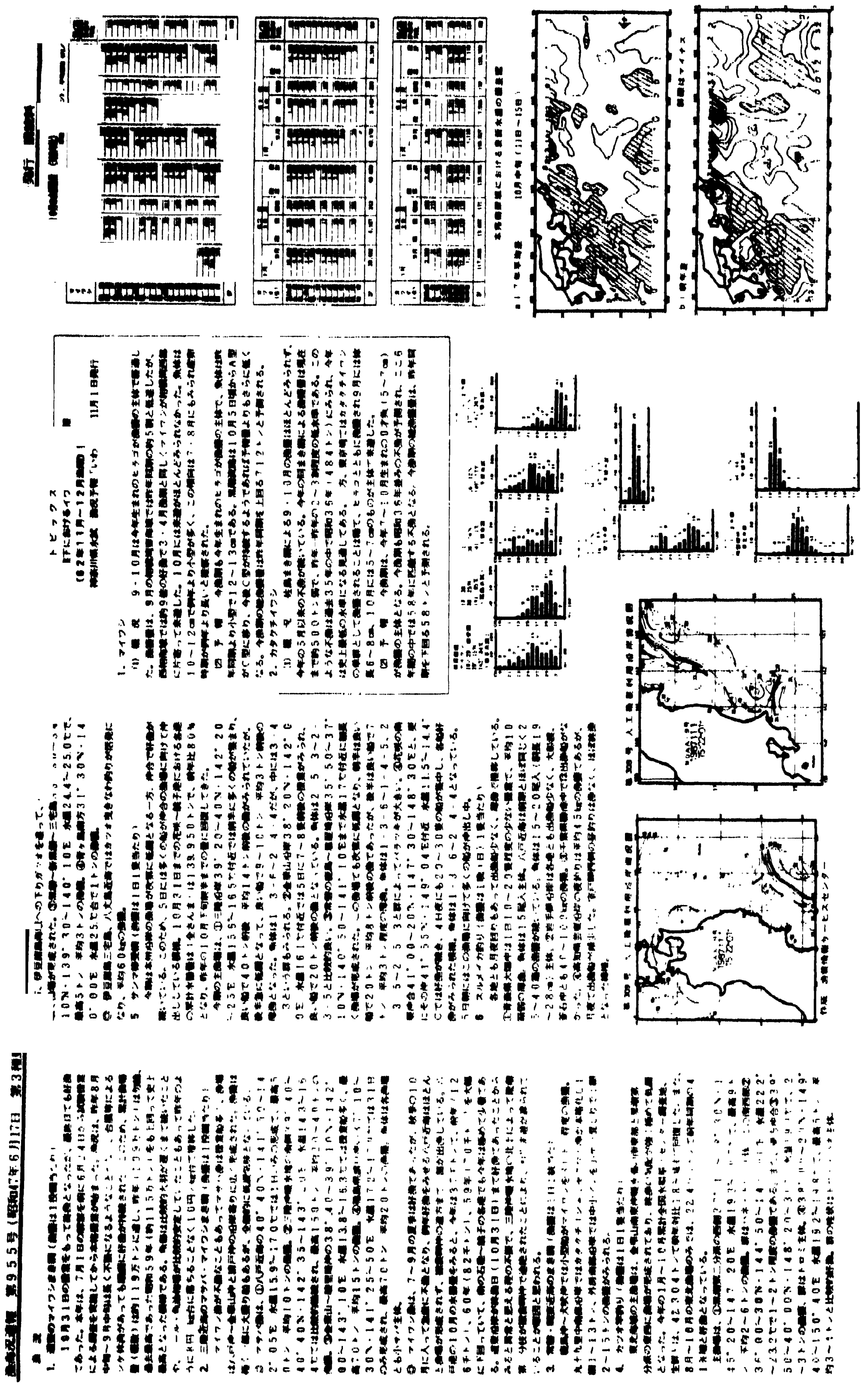


Figure 4-B An example of the Prompt Report of fisheries forecast in coastal waters around Japan (back).

are printed as Fisheries Oceanographic Information by Satellite[1] together with an explanatory text, and disseminated to the recipients (see Figures 5-A and 5-B). The information is usually issued two days.

A special telephone link is now being constructed between the JFIC and the JMSC.MT so that the satellite imagery can be transferred by cable to the JFIC more quickly and safely.

2.6 Dissemination of Forecast

There are two dissemination routes employed by the JFIC.

(1) Members at sea

Forecasts are immediately broadcasted to fishing vessels at sea by radio and radio-facsimile through the Japan Fisheries Radio Station network.

(2) Members on land

The Prompt Reports are delivered to members on land by mail or facsimile. The public radio and TV broadcasting services[2] also broadcast the latest forecast as part of the news report in a special programme for coastal fisheries.

The frequency of dissemination differs according to type of report and dissemination route. For instance, although the Pompt Report is issued at 3 to 10 day intervals, the members can gain access to the substantive contents of the report more frequently and quickly if they have a facsimile system. The Information by Satellite is delivered three times a week to members both at sea and on land.

3. OCEANOGRAPHIC ENVIRONMENT

3.1 General Features

The oceanographic features of waters around Japan are highly complicated and dynamic involving various sea currents, both warm and cold, a number of water fronts where different sea currents and/or water masses converge, usually accompanied by a number of eddies, and their displacement, etc. These complexities generally provide a highly favourable environment for marine resources in the region, and ultimately for fisheries production, with about 8 to 9 million tons annual catch in recent years, which is the highest catch among the world's oceans (Nasu, 1975, Chikuni, 1985). In this paper, however, only a few features which are closely linked with fisheries forecasting are highlighted. Figure 6 illustrates these features.

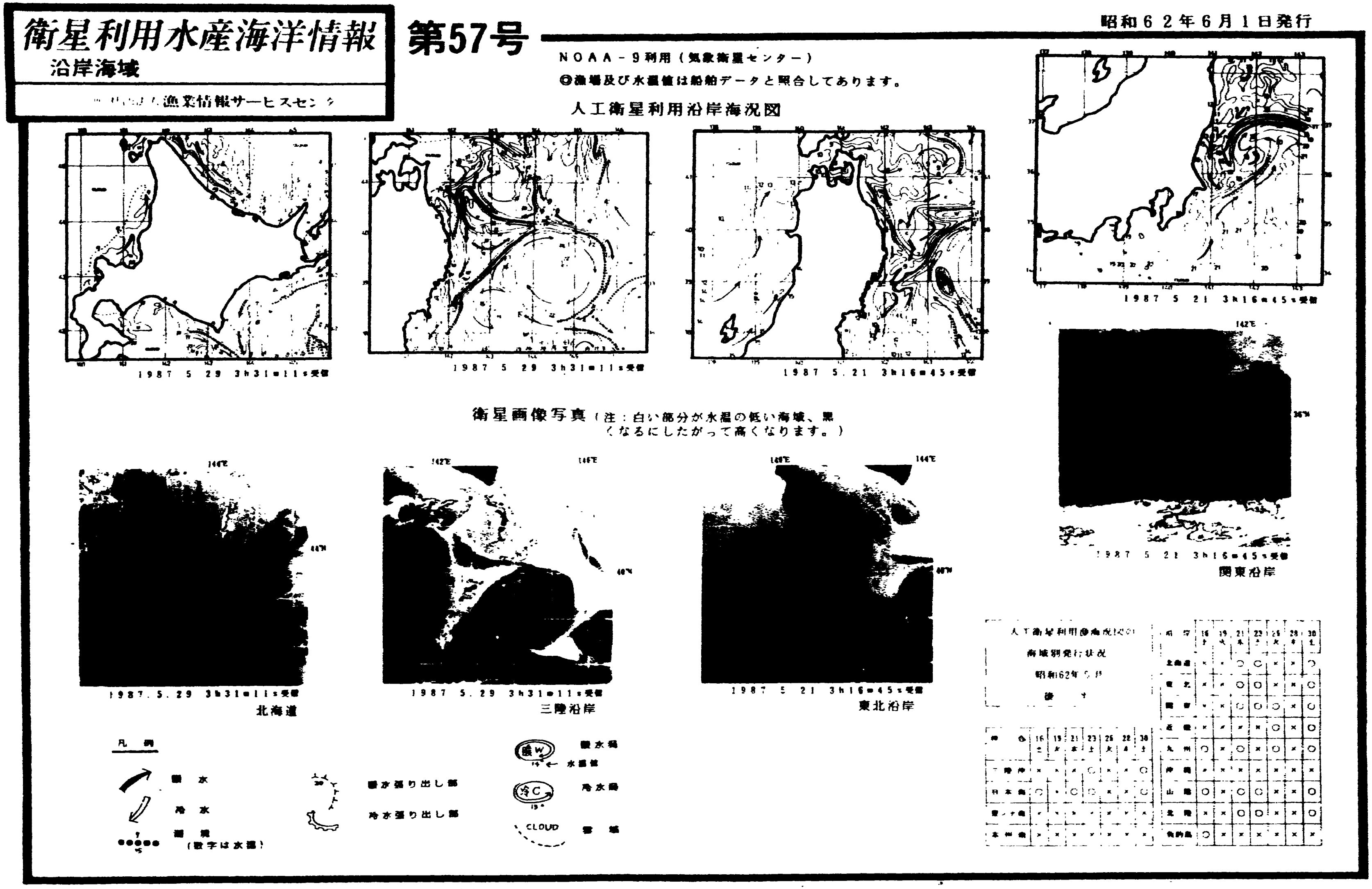
One of the most important features from the forecasting point of view is the existence of many distinguishable water fronts. Along the Pacific coast, the warm Kuroshio runs from the south while the cold Oyashio comes down from the north, and both converge off the northeast coast of Honshu (the central main island of Japan) forming a huge and sophisticated water front there. These environments provide the fisheries with highly productive fishing grounds for several fish species including both warm - and cold - water species, especially migratory pelagic fish such as skipjack tuna, Japanese chub (common) mackerel, Japanese sardine and bluefin tuna for the warmer water species group and Pacific saury and Japanese flying squid for the colder water species group.

In the Japan Sea, the Tsushima Warm Current, a prominent branch of the Kuroshio diverging off the southwestern coast of Japan or at the eastern fringe of the East China Sea around the Ryukyu Islands, runs from the south while the cold Liman and North Korean Currents run from the northwest. These converge at the southwestern to central part of the Japan Sea, forming various water fronts and providing consequently good fishing grounds for Japanese flying squid, pink salmon and Pacific saury (the Japan Sea stock, being separated from the Pacific stock), etc.

In the East China Sea, a distinguishable water front is formed between northerly branches of the Kuroshio, which diverged from the main flow in the eastern East China Sea, and the eastern fringe of the cold continental coastal water mass which extends from the Chinese coast. The waters around this front are one of the major spawning grounds of Japanese Jack mackerel and are also the southern boundary of the migratory range of many important demersal fish stocks, where good fishing grounds are generally formed during the southerly migratory period, e.g. fleshy prawn, etc.

1/ "Eisei Riyo Suisan Kaiyo Joho" in Japanese.

2/ Japan Broadcasting Corporation, "Nihon Hoso Kyokai" in Japanese.



衛星利用水産海洋情報

沿岸海域

漁業情報サービスセンター

第57号

昭和62年6月1日発行

NOAA-9利用（気象衛星センター）

◎漁場及び水温値は船舶データと照合してあります。

人工衛星利用沿岸海況図

1987 5 29 3h31m11s受信

1987 5 29 3h31m11s受信

1987 5.21 3h16m45s受信

1987 5 21 3h16m45s受信

衛星画像写真（注：白い部分が水温の低い海域、黒くなるにしたがって高くなります。）

1987.5.29 3h31m11s受信

北海道

1987 5.29 3h31m11s受信

三陸沿岸

1987 5 21 3h16m45s受信

東北沿岸

1987 5 21 3h16m45s受信

関東沿岸

凡例

暖水

冷水

潮境（数字は水温）

暖水張り出し部

冷水張り出し部

暖水塊

水温値

冷水塊

雲域

人工衛星利用海況図の

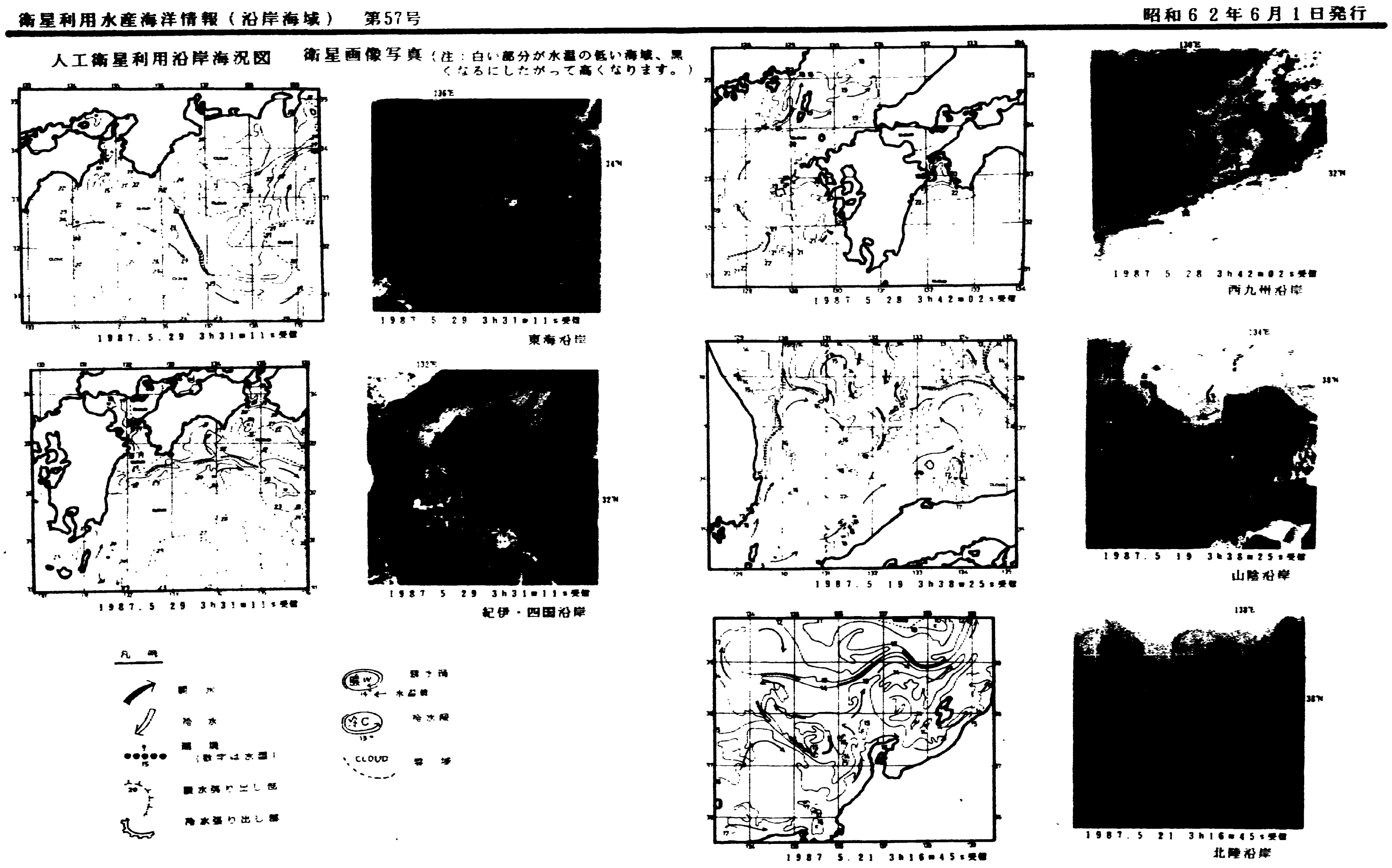
海域別発行状況

昭和62年5月

海域	16 土	19 火	21 木	23 土	26 火	28 木	30 土
三陸沖	×	×	×	○	×	×	○
日本海	○	×	○	○	×	×	○
東シナ海	×	×	×	×	×	×	×
本州南	×	×	×	×	×	×	×

海域	16 土	19 火	21 木	23 土	26 火	28 木	30 土
北海道	×	×	○	○	×	×	○
東北	×	×	○	○	×	×	○
関東	×	×	○	○	○	×	○
近畿	×	×	×	×	○	×	○
九州	○	×	○	×	○	×	○
沖縄	×	×	×	×	×	×	×
山陰	○	×	○	○	×	×	○
北陸	×	×	○	○	×	×	○
[illegible]	○	×	×	×	×	×	×

Figure 5-A An example of Satellite Imagery Report for fisheries forecast in coastal waters around Japan (front).



衛星利用水産海洋情報（沿岸海域）　第57号　　昭和62年6月1日発行

人工衛星利用沿岸海況図　　衛星画像写真（注：白い部分が水温の低い海域、黒くなるにしたがって高くなります。）

1987.5.29 3h31m11s受信

1987 5 29 3h31m11s受信
東海沿岸

1987.5 29 3h31m11s受信

1987 5 29 3h31m11s受信
紀伊・四国沿岸

1987 5 28 3h42m02s受信

1987 5 28 3h42m02s受信
西九州沿岸

1987.5 19 3h38m25s受信

1987.5 19 3h38m25s受信
山陰沿岸

1987 5.21 3h16m45s受信

1987.5 21 3h16m45s受信
北陸沿岸

凡例

暖水
冷水
潮境（数字は水温）
暖水張り出し部
冷水張り出し部
暖水渦
水温線
冷水渦
雲域

Figure 5-B An example of the Satellite Imagery Report for fisheries forecast in coastal waters around Japan (back).

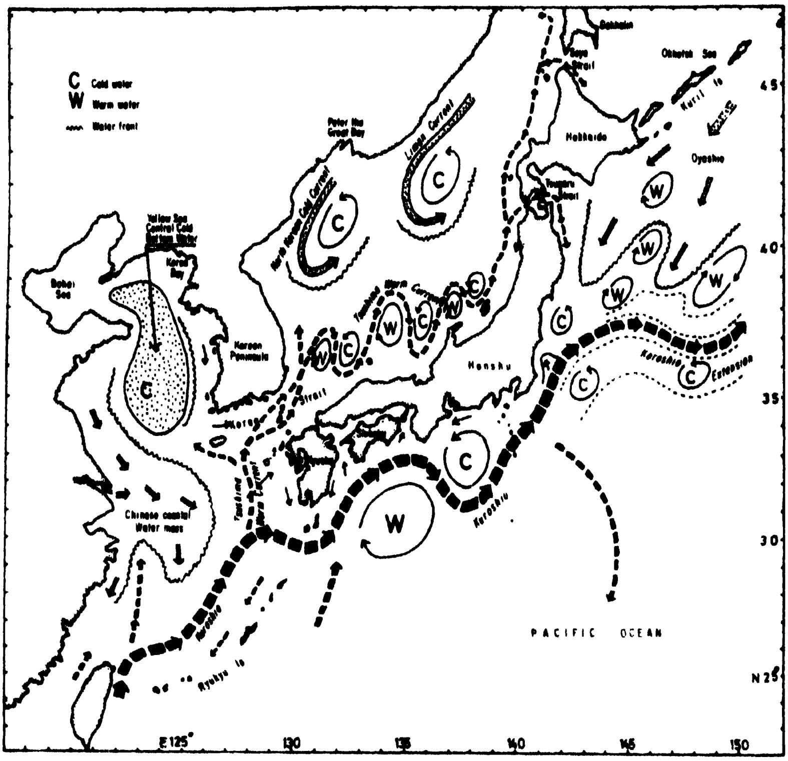


Figure 6 Schematic illustration of the oceanographic features of the waters around Japan.

Besides the above, water fronts are sometimes formed around sea-mounts and reefs when specific topographic features and sea currents combine.

Large-scale warm or cold water masses, which have been separated from their original bodies (the Kuroshio, Oyashio, or others) in conjunction with dynamic meanderings of original bodies, often form highly complicated and dynamic water fronts. Such phenomena are commonly observed along the Pacific coast of Japan and affect greatly the fishing conditions for many pelagic fish stocks. Moreover, these water masses also affect occasionally their original or other sea currents, which results in a change of route or in the original body being compelled to form a secondary meandering. These isolated water masses vary greatly in size, location and the way they move. They influence greatly the displacement/migration pattern and schooling/swarming nature of fish, and ultimately the fishing conditions for these fish stocks.

Observation of these phenomena and projection of their change in the immediate future are, therefore, extremely important in fisheries forecasting. This is one of the reasons why the JFIC allocates considerable time and space to forecasting these oceanographic phenomena in its Prompt Report and other information material.

3.2 Pacific Ocean

The Kuroshio and the Oyashio are the most prominent sea currents running along the Japanese coast. The former originates in the tropics further south and warm (25-27°C at the surface layer in the summer) while the latter originates in the boreal seas to the north and cold (6-10°C in summer).

The Kuroshio's main influence upon fisheries can be traced to its dynamic and large-scale meanderings, which take place mostly along the central to southern Pacific coast of Japan. The meanderings, when they occur, usually encircle a sizeable cold water mass, sometimes as large as 100 miles in diameter. This cold water mass usually lasts from 2 to 9 years, changing its location and shape in accordance with changes in surrounding sea conditions, and a strong westerly counter current to the Kuroshio occurs along the southern coast of the Honshu. The Kuroshio too, which is originally the constructor of the cold water mass, is affected by the above, shifting its course further south or/and east. These phenomena greatly influence the ecological features of many pelagic fish stocks; distribution, migration, schooling, success or failure in spawning, early survival, etc.

When the meanderings take place in offshore waters along the east to northeast coast of the Honshu, where the Kuroshio and the Oyashio converge, the upper part of the current is sometimes isolated from the main flow of the Kuroshio, forming a separate warm water mass. It moves slowly northward, usually without diffusing rapidly or mixing with surrounding cold water originating from the Oyashio. The reverse phenomenon frequently takes place at the tip of the Oyashio, producing a number of isolated cold water masses. Thus, the water front between these two major currents is highly dynamic and variable in nature, not only in the location and shape of the front, but also in the complexity of the mosaic-like structure of water masses in the region. Many pelagic fish stocks, including Pacific saury, Japanese chub mackerel, skipjack tuna and Japanese flying squid, react sensitively to these changes, which influence critically on fishing especially to locate good fishing grounds.

The origin of the Oyashio, a prominent cold sea current along the northern Pacific coast of Japan, is an outflow of the very cold Bering Sea Gyre, which runs down southwest along the Kamchatka Peninsula, and is called the East Kamchatka Current. A branch of the current flows into the Okhotsk Sea, forming the Okhotsk Gyre. The water is further cooled and enriched with nutritious organisms, and rejoins the main flow again around the Pacific coast of the southern Kuril Islands to form the Oyashio. It flows further south along the east and southeastern coast of the Hokkaido (the northernmost large island of Japan), and reaches the northeast and eastern Pacific coast of the Honshu, where it converges with the northern end of the Kuroshio forming a large and dynamic water front as mentioned above. In winter the westernmost part of the Oyashio forms a complicated water front with the tip of another warm current in nearshore waters along the northeastern coast of the Honshu. This warm current is an outflow of the Tsushima Warm Current from the Japan Sea (see the next sub section) through the Tsugaru Strait (the strait between the Hokkaido and the Honshu). Although this front is not very large, it affects greatly the local nearshore fisheries.

3.3 Japan Sea

In the Japan Sea the Tsushima Warm Current is one of the prominent sea currents, and is a large branch of the Kuroshio which diverges from the main current in the easternmost part of the East China Sea along the Ryukyu Islands, and flows into the Sea through the Korea Strait (the strait between the Kyush, the westernmost large island of Japan, and the Korean Peninsula). The current usually behaves in one of two ways: sometimes it has a fairly stable route, running parallel to the Japanese coast, and at others it mostly meanders. The former generally occurs in summer and the latter in winter. However, either mode may change to the other regardless of season when the current is subject to abnormal environmental conditions, e.g. very low temperatures in summer or very high temperatures in winter. Figure 7 shows these two patterns.

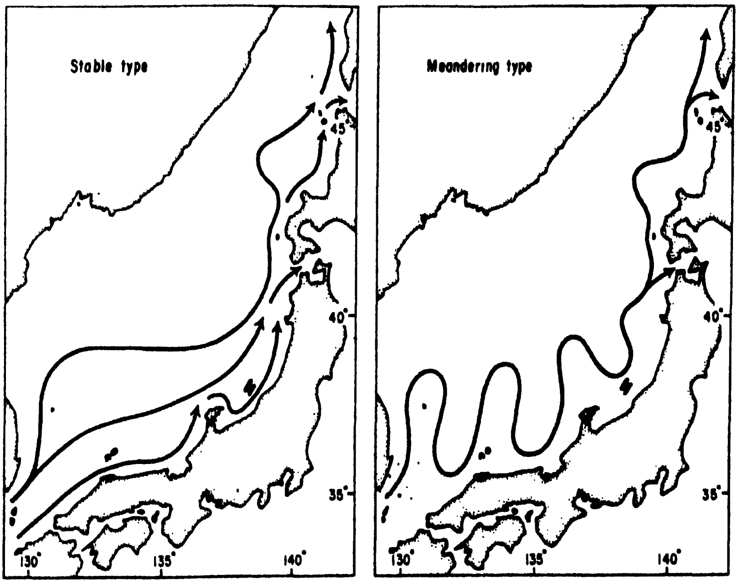


Figure 7 Schematic illustration of two types of course of the Tsushima Warm Current in the Japan Sea.

In both cases the current, runs north along the Japanese coast and reaches the southwestern coast of the Sakhalin, but hardly reaches the Tatar Strait. A substantial part of the current flows out into the Pacific Ocean through the Tsugaru Strait (the strait between the Hokkaido and Honshu) and forms various water fronts with the western part of the Oyashio as mentioned in the previous subsection. A minor part of the current also flows out of the Japan Sea further north into the Okhotsk Sea, through the Soya Strait (the strait between the Sakhalin and Hokkaido). The remaining current then diverts in a counter-clock wise direction and moves down along the USSR coast, where mixing with cold waters takes place, which is known as the Liman Current. Excessive cooling occurs during winter owing to the severe climate along the eastern Siberian coast. The Liman Current runs further west down to the east coast of the Korean Peninsula through the Peter the Great Bay. Complicated water fronts with a mosaic-like structure are formed at the convergence of the Liman and Tsushima Warm Currents. These features resemble those formed by the Oyashio and the Kuroshio along the Pacific coast of Japan, and affect greatly fishing conditions for many pelagic fish stocks in the Japan Sea, e.g. Japanese flying squid, Pacific saury (Japan Sea stock) and pink salmon.

The "North Korean Cold Current" (the local name[1/], but it is actually one of the extensions of the Liman Current) runs in a southwesterly direction along the northeastern Korean Peninsula, then turns east and rejoins the other easterly and southerly extensions of the Liman Current, which contributes to the formation of a complicated water front with the Tsushima Warm Current, as described above.

3.4 East China Sea and Yellow Sea

Figure 8 illustrates the hydrographic structure of the Yellow Sea and the East China Sea. A large, cold and saline water mass called the "Yellow Sea Central Cold Bottom Water", is located in the middle to bottom layer of the central Yellow Sea during summer to autumn each year. The water has been formed during the winter by mixing a northerly branch of the Tsushima Warm Current heading toward the central Yellow Sea, which is called locally the "Yellow Sea Warm Current", and the very cold but highly nutritious coastal waters along the western Korean Peninsula to the Shandong and Jiangsu provinces of China through the Korea Bay and the Bohai Sea.

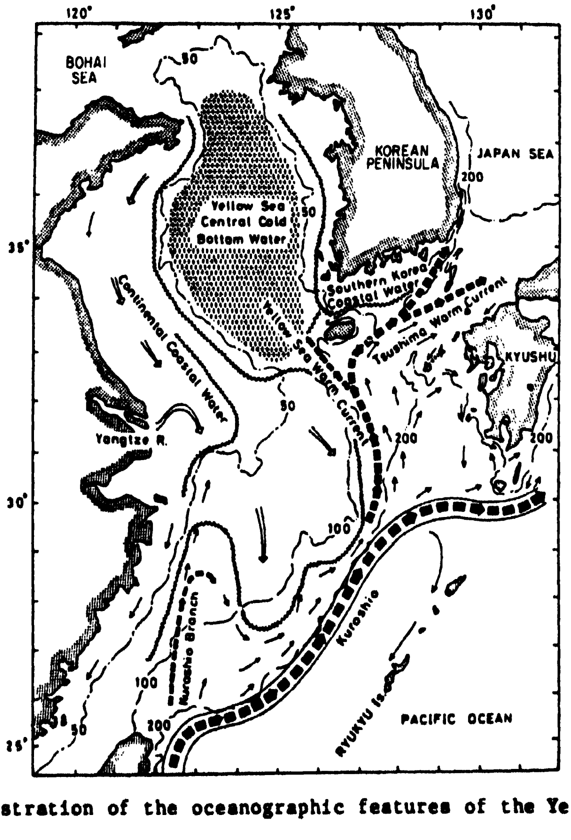


Figure 8 Schematic illustration of the oceanographic features of the Yellow Sea and East China Sea (Inoue, 1981).

[1/] Similarly, a western branch of the Tsushima Warm Current, which runs in a northeasterly direction along the southeastern coast of the Korean Peninsula, is called locally the "East Korean Warm Current".

The coastal waters along the northern Chinese coast are greatly influenced by the large-scale dilution caused by a massive inflow of freshwater from many large rivers and their numerous branches, i.e. the Yalu, Liao, Luan, Huang (Yellow), and Yangtze Rivers. The waters are therefore characterized by low salinity and high nutrition, which enhance the biological productivity of many fish stocks in the region.

During the winter very cold air moves regularly from the Asian continent over the Yellow and East China Seas at 4 to 5 day intervals, which greatly cools the surface waters of these seas and, as a result, vertical mixing takes place over all the coastal waters from surface to bottom due to convection. This is the principal process employed in the formation of the "Yellow Sea Central Cold Bottom Water". At the same time the surface water extends south and southeast, forced by the strong cold northwesterly winds caused by high atmospheric pressure over the interior of the continent. Thus distinguishable water fronts are formed with the Kuroshio along the eastern and southeastern fringe of the East China Sea. This affects greatly the fishing for pelagic fish stocks. Mixing occurs to some extent where these waters converge, and the mixed waters are mostly carried away into the Japan Sea by the Tsushima Warm Current.

The oceanographic conditions in these Seas are highly variable, and time-spatial changes or fluctuations in these water masses commonly take place, especially around the front area, in accordance with changes in meteorological conditions over the Seas. The appearance, persistency, and/or disappearance of both cold and warm water masses in the region is a key factor not only in short-term fishing conditions but also in long-term changes in stock abundance.

4. BIOLOGICAL FEATURES OF FISH AND FISHERIES FORECASTING

A brief but fairly comprehensive review of the species-specific biological features of eight fish species and the fisheries for which the forecasting service has been employed are given here to clarify the technical implications of forecasting for each. This should facilitate better understanding of the discussions in succeeding sections of this paper. Regarding the details of the subject and the references for the relevant studies carried out so far, it is suggested that readers refer to a paper prepared and published by FAO (Chikuni, 1985).

Table 3 gives the catch of major pelagic fish by species and fisheries taken in 1985, for which fisheries forecasting service has been employed. Table 4 shows the annual changes in these species catches together with the global total catch (all species combined) taken by all fisheries from the waters around Japan during 1976 to 1985.

The species names employed in this paper are those defined by FAO. The other names commonly or locally used are shown in parentheses and the Japanese names in quotation marks.

4.1 Japanese Sardine, *Sardinops melanosticta* (Temminck et Schlegel) "Ma-iwashi"

(1) Distribution

Entire coastal waters around Japan and the western Japan Sea, from the Okhotsk Sea (Pacific side) and the Primorskaya Province of USSR (Japan Sea side) in the north to the East China Sea in the south (see Figure 9).

(2) Population structure

Four sub-populations have been identified: the (i) Pacific, (ii) Ashizuri[1], (iii) Kushu and (iv) Japan Sea sub-populations. The distribution range of each is variable, expanding or contracting in accordance with change in stock abundance. When abundance is very high, intermingling is common between (i) and (ii), and between (iii) and (iv). Figure 9 illustrates this.

(3) Spawning

Spawning takes place during December to June when the water temperature is 12-20°C, with a peak season from February to May. Average age at first maturity is 2, generally younger in southern and older in northern sub-populations. It also varies according to the change in stock abundance or density. Figure 9 shows the location of major spawning grounds and seasons for each sub-population.

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[1] "Ashizuri" refers to the name of a cape located at the southwestern tip of the Shikoku (a large island facing the southwestern part of the Honshu), which is a very important spot from various scientific points of view, e.g., geography, geology, meteorology, oceanography, botany, ornithology and marine biology. The "Ashizuri sub-population", therefore, refers to the stock which has its main spawning ground and habitat in the waters adjacent to the cape (see, Figures 9 and 19).

Table 3

Catch of major pelagic fish species by fishing gear taken from the waters around Japan in 1985, for which fisheries forecasting has been employed1/.

('000 t)

Species / Fisheries	Japanese sardine	Japanese anchovy	"Shirasu"2/	Japanese3/ chub mackerel	Japanese Jack mackerel	Japanese amberjack (yellowtail)	Pacific saury	Skipjack tuna	Japanese flying squid
(1) Large- to medium-scale purse seine (one and two boats)	2 778	6	-	541	85	0	-	21	-
(2) Small-scale purse seine (one and two boats)	707	92	-	133	51	9	-	0	-
(3) Boat seine	53	89	94	1	1	0	0	0	0
(4) Saury stick-held dipnet	0	-	-	0	-	-	242	-	0
(5) Other dipnet	8	5	1	49	2	0	0	0	0
(6) Skipjack pole-and-line	-	-	-	0	-	0	-	72	-
(7) Squid jigging	0	-	-	-	0	-	-	0	122
(8) Other angling	-	-	-	10	3	7	0	4	0
(9) Gillnet	1	0	-	0	0	5	1	2	0
(10) Setnet	232	13	0	24	9	12	3	1	6
(11) Trawl (various)	0	0	0	0	0	0	-	0	4
(12) Beach seine	1	0	0	0	0	0	0	0	0
(13) Other fisheries	87	1	0	13	7	0	0	7	1
(14) Total4/	3 866	206	95	771	158	33	246	107	133

1/ Source: Japanese Yearbooks of Fisheries Statistics and Fisheries and Aquaculture Production by FAO Fishing Area, both published by the Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries.

2/ "Shirasu" is the post-larvae (15-35 mm body length) and juveniles (35-50 mm) of mostly Japanese anchovy and partly Japanese sardine, see text for the details.

3/ Statistics include a small amount of the catch of "Spotted chub mackerel", see text for details.

4/ See Table 4 for the account (magnitude of importance) in the global total production in the region.

Table 4

Nominal catch of major coastal pelagic fish in the waters around Japan during the past decade[1]

('000 t)

Species	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Japanese sardine	1 066	1 420	1 638	1 817	2 198	3 089	3 290	3 745	4 179	3 866
Japanese anchovy	217	245	152	135	151	160	197	208	224	206
"Shirasu"[1]	60	42	41	55	55	53	73	94	71	96
Japanese chub mackerel[1]	979	1 355	1 625	1 414	1 301	908	718	804	813	771
Japanese Jack mackerel	128	88	59	84	156	65	109	135	139	158
Japanese amberjack (yellowtail)	43	27	37	45	42	38	38	42	41	33
Pacific saury	105	253	360	278	187	160	207	239	210	246
Skipjack tuna	149	127	152	160	170	99	127	152	225	107
Japanese flying squid	312	264	199	213	331	197	182	192	174	133
(A) Total (above species only)	3 059	3 821	4 263	4 201	4 491	4 769	4 941	5 611	6 076	5 616
(B) Global total catch (all species combined)[2]	6 637	7 005	7 508	7 411	7 741	7 978	8 142	8 565	9 221	8 766
Ratio: A/B (%)	46	55	57	57	58	60	61	66	66	64

1/ See the footnotes on Table 3 for the explanatory notes.

2/ The "global total catch" refers to the combined total catch of marine fisheries classified as the coastal and offshore fisheries, but excludes the distant water fisheries, in nominal catch statistics. All species caught are therefore included, including demersal fish, oceanic fish such as tunas and billfish, etc.

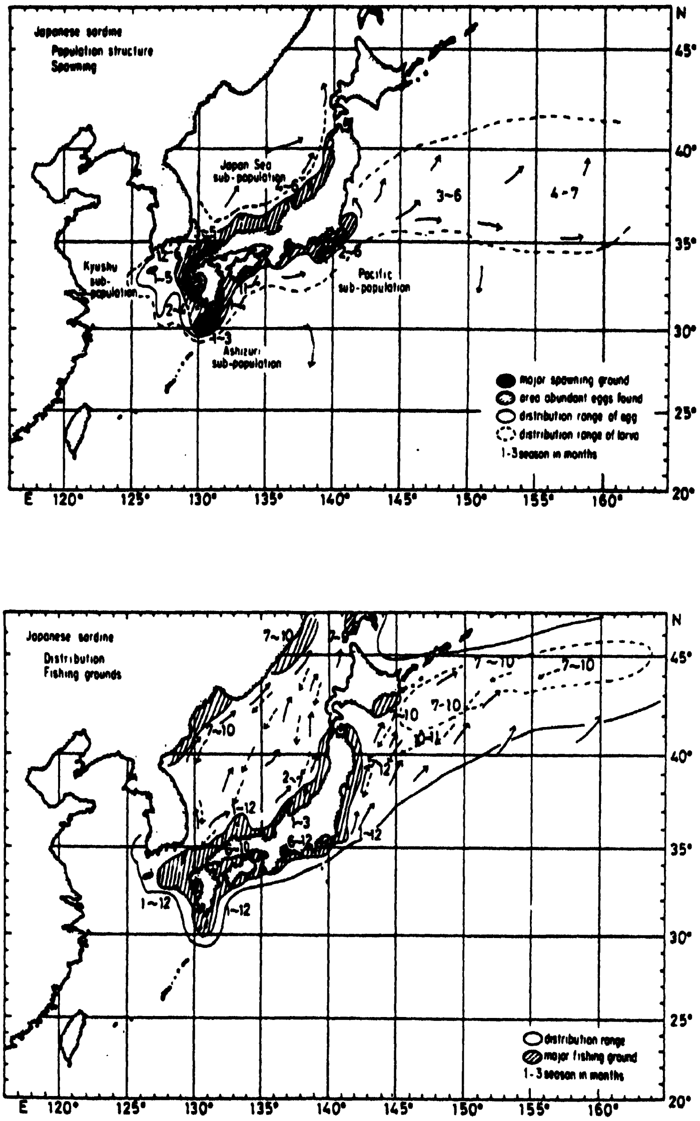

Figure 9 Population structure, spawning, distribution range, major fishing grounds and seasons of Japanese sardine.

(4) Early life form

Eggs hatch about 3 days after spawning at 15°C water temperature. Hatched larvae are about 3.3 mm in total length (TL) and absorb yolk during 3 days after hatching, growing to about 5.5 mm (TL) post-larvae. The post-larvae and juveniles smaller than 40 mm are called "shirasu" in Japanese. The early survival rate during the egg to "shirasu-stage" is very low and extremely variable. This may be one of the major reasons why the year-class strength of Japanese sardine fluctuates greatly.

(5) Growth

The range of body length (BL) at the end of each age are: age-0: 13-16 cm, age-1: 17-20 cm, age-2: 19-22 cm, age-3: 21-23 cm, age-4: 21-24 cm, and age-5: 22-24 cm. The lifespan is estimated to be 5 to 6 years.

(6) Migration

Each sub-population migrates north-south, leaving and returning to their spawning grounds (i.e. where the fish were born). Figure 9 shows these movements schematically.

(7) Feeding habits and predators

Larvae feed mostly on small zooplanktons, e.g. fish and other animal eggs, nauplii and adults of copepods, etc. After the larval stage the fish feed intensively on both larger zooplanktons and phytoplanktons. Many larger fish, such as skipjack and other tunas, billfish, amberjack and Spanish mackerel, squids and dolphins are major predators throughout life.

(8) Fisheries

The majority of the Japanese catch has been taken mostly by purse seines, both one-boat and two-boat seines, (about 90 percent), partly by other gears including setnet (6 percent), boatseine (0.5 percent), and other small-scale gears (Table 3). Good fishing grounds are located often in areas where coastal waters have been compressed or encircled by large sea currents such as the Kuroshio, Oyashio or Tsushima Warm Current.

(9) Production

Total production in 1985 was about 3.9 million tons, a major marine catch in Japan, accounting for about 45 percent of the total coastal and offshore production of about 8.8 million tons (Table 4). However, it is well known that Japanese sardine stocks accompany tremendously large fluctuations in stock abundance. Accordingly, sudden and large increases or decreases in the total catch for the sardine fisheries have been historically experienced. For instance, total production in 1965 was only about 9 000 tons, the catch in 1985 had therefore increased by a factor of 430 over the preceding two decades.

4.2 Japanese Anchovy, Engraulis japonica (Houttuyn)
"Katakuchi Iwashi"

(1) Distribution

Like Japanese sardine, the fish is widely distributed throughout the coastal and nearshore waters in the Far East, from the Okhotsk Sea in the north to the East China Sea in the south through waters around Japan and the Korean Peninsula. The fish, in contrast to other neritic pelagic fish species in the region prefer inshore waters, which indicates the euryhaline nature of the species (Figure 10).

(2) Population structure

In the waters around Japan, four sub-populations have been identified, they are almost independent to each other, including: the (i) Honshu-Pacific, (ii) Kyushu-Pacific, (iii) West Kyushu and (iv) Japan Sea sub-populations (Figure 10).

(3) Spawning

Spawning takes place all the year round at water temperatures ranging from 12° to 28°C, a distinctive feature of the fish that shows its eurythermal nature. However, two peaks are generally observed, one in spring and the other in summer, when water temperature ranges from 15° to 21°C. The duration of the peak season is usually longer in the south than in the north. Figure 10 shows major spawning grounds and seasons around Japan.

(4) Early life form

Eggs take about 30 hours to hatch at 20°C, releasing larvae of about 2.6 mm total length (TL). Larvae grow into post-larvae 3 days after hatching and start feeding on their own. The post-larvae (about 15 mm TL) and juvenile fish smaller than 40 mm TL are called "shirasu", like those of Japanese sardine. The "shirasu" catch is composed mostly of anchovy with some sardine.

(5) Growth

The range of body-length (BL) of a spring-brood at the end of each age are: age-0: 7-9 cm, age-1: 9-12 cm, age-2: 12-15 cm. The span of life is around 2.5 years.

(6) Migration

The fish is rather sedentary in nature and hardly moves any distance. The specimens occasionally found in far offshore waters off the northeast Pacific coast of Japan (Figure 10) are, presumably, those carried by sea currents. However, the vertical displacement appears to be large and frequent as the fish are often caught by both surface and bottom gears.

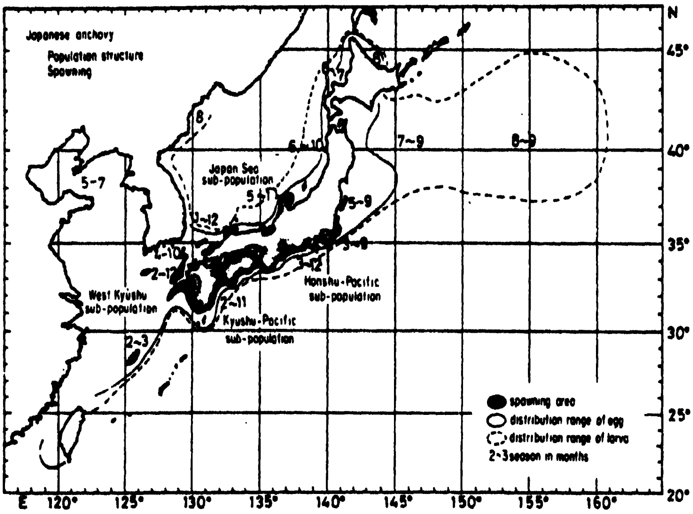

Figure 10 Population structure, spawning grounds and distribution pattern of eggs and larvae of Japanese anchovy.

(7) Feeding habits and predators

Larvae feed mostly on nauplii and copepodids of copepods. As they grow, the fish prefer larger zooplanktons, chiefly adult copepods, while occasionally feeding on phytoplanktons, mostly diatoms. The fish is an important prey for piscivorous fish in the marine ecosystem. Many larger fish, including both pelagic and demersal fish, feed intensively on achovy. It has been estimated that the predatory loss in many waters far exceeds the total catch by the fisheries there.

(8) Fisheries

Anchovy fishing in Japan has been carried out by two different types of fishery. One is the ordinary anchovy fishery aiming at older juvenile and adult fish. The other is the "shirasu" fishery aiming at post-larvae (15-35 mm TL) and younger juvenile fish (30-40 mm BL). This is a peculiar feature of the exploitation of anchovy in Japan. The majority of the catch in the former fishery has been taken by both small-scale purse seine (about 45 percent) and boat seine (about 40 percent). The "shirasu", on the other hand, has been caught almost exclusively by boat seine (Table 3). The annual catch of "shirasu", amounting to 60-90 000 tons, accounts for about 30 percent of the total anchovy production in weight. However, the number of individuals caught is roughly more than 10 times that of the adult fish catch, which indicates the intensive fishing on the entire anchovy stocks in the region.

(9) Production

The total catch, including "Shirasu" has been fairly stable at about 200-300 000 tons during the past decade (Table 4). The abundance of stocks have never decreased drastically or increased remarkably, in contrast to that of Japanese sardine stocks. This, considering also the intensity of "shirasu" fishing, is clear evidence of the resistive and tolerant nature of the fish against environmental changes and heavy fishing.

4.3 Japanese Chub Mackerel, Scomber japonicus Houttuyn[1/]
(Common mackerel) "Ma-saba"

(1) Distribution

The fish has been found widely in warm waters in the North Pacific Ocean, namely waters around Japan in the northwest, the East China Sea to the Philippines in the west and south, waters around Hawaii in the central and the west coast of North America in the east. However, fish reported from each area mentioned above appear to be separated as different populations.

[1/] Strictly speaking, the commercial catch includes a small amount of spotted chub mackerel, Scomber australasicus Cuvier, "Goma-saba", owing to the difficulty in separating the species on board. The catch is estimated to account for about 5 percent in northern waters and about 15-25 percent in southern waters.

(2) Population structure

In the waters around Japan, four sub-populations have been identified: the (i) Pacific, (ii) West Kyushu, (iii) Japan Sea and (iv) East China Sea sub-populations. It seems that further localized stocks exist within these sub-populations.

(3) Spawning

The age at first maturity is estimated to be 2 to 3, varying slightly by sub-population. The spawning season also differs by sub-population, however, the peak season is from March to May for all stocks when water temperature ranges from 15 to 18°C. The spawning grounds are in many of the same areas as those of Japanese sardine, but tend to extend further offshore. Figure 11 shows these features.

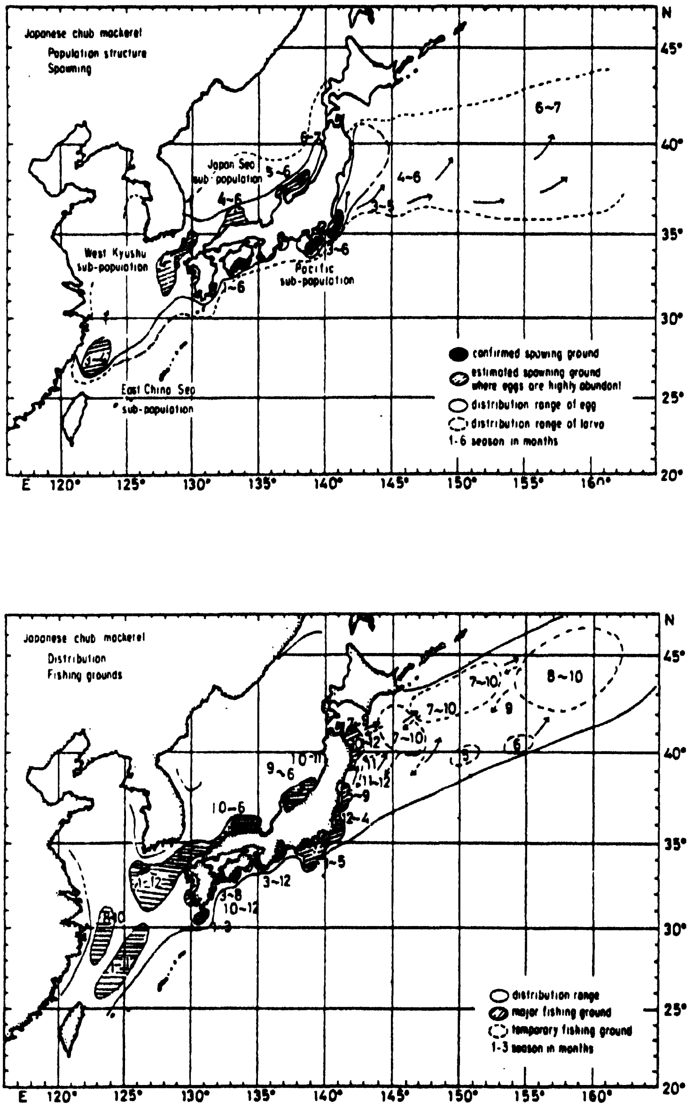

Figure 11 Population structure, spawning, distribution range, major fishing grounds and seasons of Japanese chub mackerel.

(4) Early life form

Hatching takes place two days after spawning at a water temperature of 20°C, releasing larvae 3.0 mm in total length (TL). The post-larvae stage starts 3 days after hatching when larvae reach around 3.6 mm TL. The post-larvae become juveniles when they have grown to 15 mm TL.

(5) Growth

The body size in fork length (FL) at the end of each age is: age-0: 20 cm, age-1: 28 cm, age-2: 33 cm, age-3: 36 cm, age-4: 38 cm, age-5: 39 cm and age-6: 40 cm. The lifespan is estimated to be around 6 years.

(6) Migration

North and south seasonal migration is annually undertaken. During spring to summer the fish move generally northward from their spawning ground for feeding, while during autumn to winter they return for spawning. The migratory range and the displacement distance differ by sub-population. Figure 11 shows these movements.

(7) Feeding habits

During the larval stage the fish feed mostly on copepods, including eggs, nauplii and adults. Then the fish change preference to larger animals in accordance with their growth, although they are plankton feeders by nature. Major food organisms for juvenile and adult fish are copepods, euphausids, amphipods and young fish including sardine and Jack mackerel.

(8) Fisheries

The majority of the catch is taken by large- to medium-size purse seine (about 70 percent), followed by small-scale purse seine (about 17 percent). They operate mostly on/along continental shelves (shallower than 200 m) with acoustic fish-finder and luring lights. In contrast to these modern fishing methods, unique and traditional fishing by scoop-net with luring light and chumming bait still exists along the central Pacific coast. However, pole and line fishing, another traditional fishing method which once predominated in the fishery during the 1950's to 1960's, has almost completely disappeared since around 1980, the fishing having been taken over by purse seines (Table 3). Figure 11 shows major fishing grounds and season.

(9) Production

Total production increased steadily during the 1950's and 1960's reaching a peak in the 1970's with 1.0 to 1.6 million tons annual catch. The catch has since declined to 700-800 000 tons in recent years (Table 4). The increase in total production in the earlier period is believed to have resulted from an increase in the abundance of many stocks coupled with the development of modern seining techniques for medium - to small-scale vessels. It is thought, on the other hand, that the decline in total production in recent years may have been caused by a decline in stock abundance due mostly to a decrease in recruitment for some reasons. However, a clear explanation for this has not yet been given.

4.4 Japanese Jack Mackerel, _Trachurus japonicus_ (Temminck et Schlegel)
(Horse mackerel), "Ma-aji"

(1) Distribution

The fish in the region are distributed in almost the same pattern as Japanese chub mackerel, i.e. in the waters around Japan to the East China Sea. However, the major concentrations are located more to the south than those of chub mackerel, where warmer water prevails (cf. Figures 11 and 12).

(2) Population structure

It is very difficult to identify the separate stocks clearly as the fish appear to have changed their population structure in accordance with changes in environmental conditions and overall stock abundance. However, the fish currently inhabiting the region can be roughly grouped into two: (i) a large group that originates from the central East China Sea and (ii) a combination of several small groups originating from a few local stocks along both the Pacific and Japan Sea coasts of Japan.

(3) Spawning

The spawning season extends from January to July but the peak season differs by locality, being generally earlier in the south, e.g. February to March in the East China Sea and March to May in the northern waters (Figure 12).

(4) Early life form

Larvae hatch out about 40 hours after spawning at a water temperature of 20°C and are about 2.5 mm in total length (TL). They reach about 3.0 mm TL about 3 days after and start post-larval stage feeding on their own. The juvenile stage starts when fish grow to 15 mm TL.

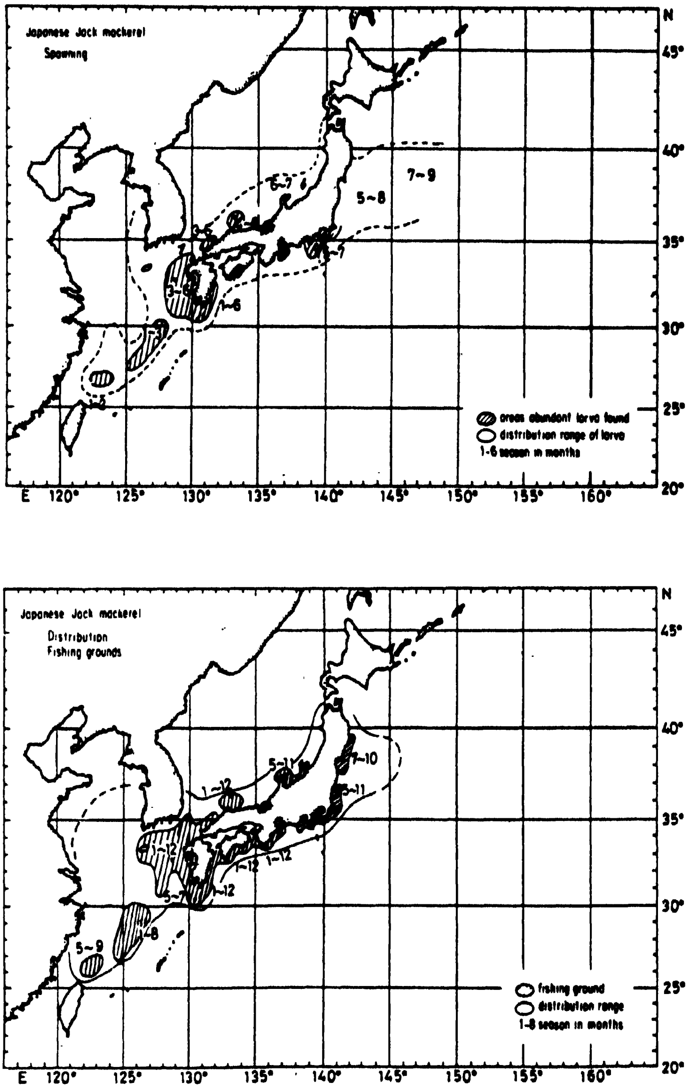

Figure 12 Major spawning grounds, distribution range, major fishing grounds and seasons of Japanese Jack mackerel.

(5) Growth

It is well known that the fish change growth rate and the age at first maturity in accordance with changes in their stock abundance. The growth rate also differs largely by stock. Body sizes in fork length (FL) at the end of each age in the current East China Sea group are: age-0: 14-16 cm, age-1: 20-22 cm, age-2: 25-27 cm, age-3: 30-32 cm and age-4: 34-36 cm. The age at first maturity is currently around 1.5 to 2, while it was around 3.5 to 4 when the stock abundance was high during the 1960's. The lifespan is estimated to be 5 to 6 years.

(6) Migration

Like other neritic pelagic fish in the region, Japanese Jack mackerel generally migrate toward the north in spring and the south in autumn (Figure 12). However, a substantial part of the stocks remains in the spawning area forming sedentary local stocks all the year around, which is one of the species-specific features.

(7) Feeding habits and predators

Larvae feed mostly on nauplii and adults of copepods. However, the fish attains rapidly an omnivorous nature in accordance with their growth. Juveniles start to feed on fish larvae, and adults feed intensively on various animals including euphausids, polychaeta, small fish and squids. It is notable that the fish is itself an important food item for other larger piscivorous fish.

(8) Fisheries

Most of the catch is taken by purse seine, accounting for about 85 percent of the total catch (Table 3). Major fishing grounds are found in both offshore and coastal waters (Figure 12). Although the amount of catch is small at 10-15 000 tons, it is noted that about 8 to 10 percent of the total catch is been caught by nearshore gears including setnets and anglings (Table 3), which indicates the sedentary nature of the fish.

(9) Production

The total catch has fluctuated a great deal over the years. Total annual production increased rapidly during the 1950's and reached about 400-450 000 tons during the 1960's. However, it has since continuously decreased to its current level of 100-140 000 tons (Table 4). It is believed that these changes in total production have resulted from a long-term change in stock abundance. However, the causes of these changes are not yet clear.

4.5 Japanese Amberjack, *Seriola quinqueradiata* Temminck et Schlegel (Yellowtail), "Buri"

(1) Distribution

The distribution range is quite similar to that of Japanese Jack mackerel, except that the northern limit extends further north and reaches the Pacific and Japan Sea coasts of the Hokkaido (Figure 13).

(2) Population structure

Identification of population structure is difficult owing to the complicated migratory pattern of the fish. However, they can be grouped into two sub-populations for practical purposes: the (i) East China Sea to Japan Sea and (ii) Pacific sub-populations, each originating probably from two different spawning grounds (Figure 13). However, intermingling and mixing of fish are assumedly quite common during their larval and adult stages, while it is apparent that the two groups are separated during the juvenile stage.

(3) Spawning

The two spawning grounds located in the waters along the southern Pacific coast of Japan and in the eastern East China Sea seem to be isolated (Figure 13). However, this does not necessarily imply the existence of two separate stocks. Spawning takes place during February to July (at water temperatures of 16-29°C) in the former grounds and during February to May (19-22°C) in the latter.

(4) Early life form

Hatching takes place about 50 hours after spawning, releasing larvae of about 3.5 mm in total length (TL). Larvae grow to post-larvae 3 days after reaching about 5 mm TL and to juveniles at about 22 mm TL. Fry and juveniles (4-10 cm TL) usually shelter under seaweeds floating on the sea, one of the peculiar features of the fish. The eggs and larvae, as well as the fish under seaweeds, are carried to northern waters by strong sea currents, i.e. the Kuroshio in the Pacific Ocean and the Tsushima Warm Current in the Japan Sea. Mixing of the two groups (sub-populations) mentioned above commonly occurs during these stages. Some of the floating fry and juveniles are collected by small seine-nets and scoop-nets and are used as seed fish for aquaculture, a peculiar aspect of the exploitation of amberjack in Japan.

(5) Growth

Rapid growth and large body size are other distinctive features of the fish. Body size in fork length (FL) at the beginning of each age are: age-1: 30 cm, age-2: 50 cm, age-3: 60 cm, age-4: 70 cm and age-5: 80 cm. Maximum size is estimated to be about 95 cm and lifespan 7 years. Age at first maturity is estimated to be 3.

(6) Migration

The juveniles, which are separated in two different zones, (the Pacific Ocean and the Japan Sea), migrate seasonally, moving north in summer and south in winter, but they seem to remain within their own zone and do not meet up until they mature. The adult fish, older than age 3, generally move further south during the winter to spring for spawning, and subsequently migrate to the north. Substantial intermingling and/or mixing between the two groups therefore occurs during the wintering and spawning of adult fish.

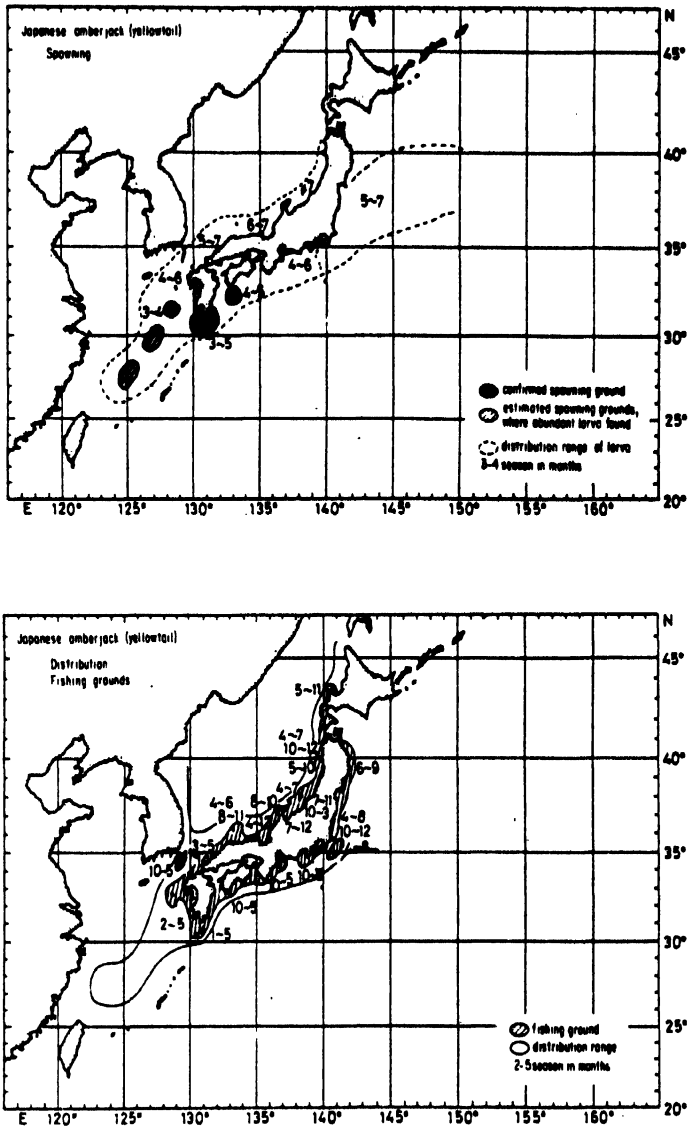

Figure 13 Major spawning grounds, distribution range, major fishing grounds and seasons of Japanese amberjack (yellowtail).

(7) Feeding habits

The larvae feed mainly on nauplii and adults of copepods. They change food preference to larger zooplanktons and smaller fish during fry to juvenile stages. The adults attain a distinctive piscivorous nature and feed intensively on the other small coastal pelagic fish including sardine, anchovy, chub mackerel, Jack mackerel and squids.

(8) Fisheries

Amberjack was traditionally caught almost exclusively by setnets until the late 1950's. However, the composition of gears employed in the fishery have drastically changed since then and the catch by setnets accounts for only about 30-40 percent of the total in recent years, being taken over by other gears, including purse seine, angling and gillnet (Table 3). However, the fishing grounds for amberjack have remained confined to nearshore and coastal zones (Figure 13), which may indicate the limited availability of the fish in offshore waters. The causes of the change in the types of gear used in the fishery are not clear, but the change in availability of the fish, especially for setnets, probably caused by a change in migratory pattern is one of the major factors. The seed fish fishery developed rapidly during the 1960's, being stimulated first by the strong demand for cultured amberjack and second by the remarkable development in mariculture technology. However, fishing has levelled off in recent years at about 80 million annual catch (number of specimens supplied to aquaculture).

(9) Production

There has been no drastic change in total production throughout the years, although a slightly declining trend is observed in the long run. It has been fairly stable in recent years at about 40 000 tons annual catch (cf. 50 000 tons during the 1950's). Nevertheless, a large change in the share among different fishing gears has taken place as mentioned previously. In contrast, aquaculture production increased rapidly during the 1970's, reaching about 150 000 tons annual production, more than triple the total catch of natural fish, but the production has levelled off since then.

4.6 Pacific Saury, Cololabis saira (Brevoort)
"Sanma"

(1) Distribution

Pacific saury is widely distributed in the temperate zone throughout the North Pacific. However, the fish are separated into four distinct stocks, as described below.

(2) Population structure

Four independent stocks have been identified in the North Pacific. These are the (i) Northeast Pacific, (ii) North-Central, (iii) Northwest Pacific and (iv) Japan Sea stocks (Figure 14). Each stock seems to be nearly completely isolated, intermingling or mixing of fish between neighbouring stocks would hardly occur throughout their life. However, not much is known about the biological features of the first two stocks. Commercial fishing has been carried out only on the last two stocks. The Northwest Pacific stock along the Pacific coast of Japan is prominent in stock biomass and habitat, while the Japan Sea stock is relatively minor, being confined to the southwestern part of the Japan Sea (Figure 15).

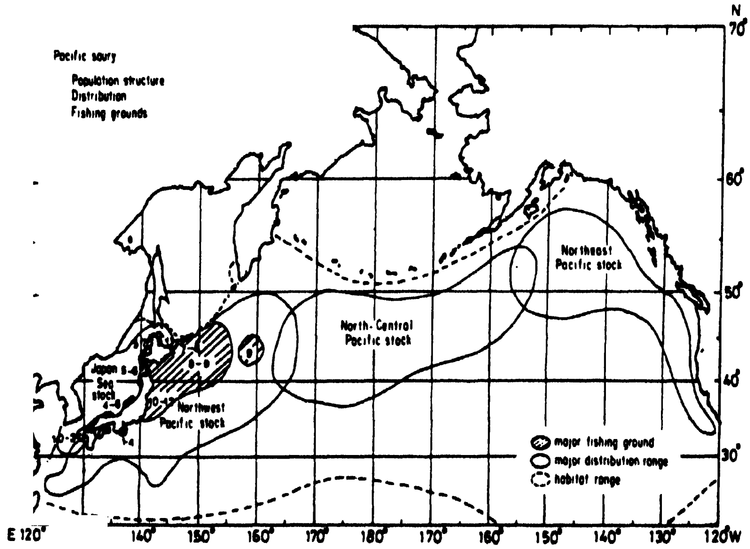

Figure 14 Population structure, distribution range and major fishing grounds of Pacific saury in the North Pacific Ocean.

(3) Spawning

The spawning ground of the Northwest Pacific stock is estimated to be very large, extending over almost all the coastal waters along the Pacific coast of Japan, however, details of offshore spawning are not well known. In contrast, spawning of the Japan Sea stock is limited to the Korea Strait and adjacent waters (Figure 15). The spawning season in the former stock is prolonged, lasting nearly all year round, but two different peak seasons are observed locally: January to April in southern waters and July to November in northern waters. Spawning in the Japan Sea stock appears to be concentrated during March to June, although eggs and larvae are observed all the year round.

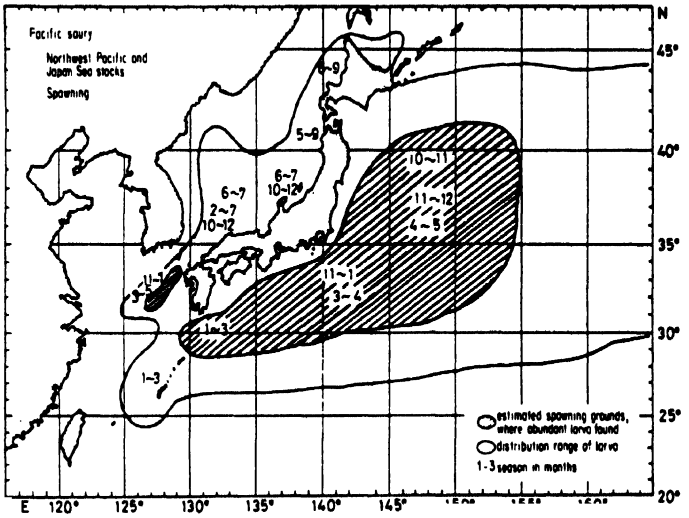

Figure 15 Estimated spawning grounds and distribution range of larvae of the Northwest Pacific and Japan Sea stocks of Pacific saury.

(4) Early life form

Eggs are adhesive, and float on the surface usually attached to floating seaweeds for about two weeks, which results in transportation in distance to the north and scattering widely. Size of hatched larvae ranges 5.3-7.8 mm in total length (TL). They reach post-larval stage three days after hatching and start feeding on their own. The juvenile stage starts when they grow to about 24 mm TL. Larvae are thus distributed over vast areas with a latitudinal range of 25-45°N, as shown in Figure 15. The water temperature in these waters ranges 10-25°C (optimum 13-18°C)in the Northwest Pacific Ocean and 7-24°C (15-19°C) in the Japan Sea.

(5) Growth

The fish grow generally very fast, but the growth rate varies greatly by specimen, area and season spawned and year. As a result, the estimated body length at the beginning of each age ranges widely, i.e. age-1: 8-15 cm, age-2: 15-25 cm, age-3: 23-33 cm. Age at first maturity is quite young, starting at around 1.5 and completing by 2. The lifespan is very short, and is estimated to be 3 years, as fish older than age-4 disappear almost completely from exploitable stocks.

(6) Migration

Despite being dispersed far and wide by sea currents during early life stages, the fish generally form many large schools and migrate seasonally to the north in summer and to the south in winter travelling long distances in both the Pacific Ocean and Japan Sea.

(7) Feeding habits and predators

The fish is a typical planktivorous species, feeding intensively on various zooplanktons including copepods, euphausids, amphipods, fish eggs and larvae. Pacific saury is, throughout its life, an important food item for other carnivorous fish and animals. Mullets, butterfish, greenlings, snipefish and lantern fish are major predators during early life stages, while tunas, billfish, salmons, mackerels, sharks, Japanese flying squids and porpoises are its major predators later in life.

(8) Fisheries

Taking advantage of the positive phototaxis and strong shoaling nature of the fish, Japanese fishery currently catches Pacific saury almost exclusively with light lured stick-held dipnets[1] mostly along the northeast Pacific coast of Japan (Table 3 and Figure 14). The fishing has been carried out during August to November[2] directing to feeding fish when they swarm along the various water fronts formed by the Kuroshio and Oyashio. This is one of the key issues to be taken into account in the fisheries forecasting for Pacific saury. Japanese saury fishing in the Japan Sea is of minor importance although the stock has been harvested by the Korean fishery along the east coast of the Korean Peninsula.

(9) Total production

The total production of Pacific saury from the Northwest Pacific stock has fluctuated a great deal, especially since around 1950 when the modern fishing technique referred to above was introduced into the fishery[3]. Annual production in recent years has fluctuated between 100 to 360 000 tons (Table 4). The fluctuation may have been caused by a combination of the changes in stock abundance and the availability or/and catchability of fish, caused mostly by changes in oceanographic conditions. Although a clear assessment is difficult to make at present, it is believed that both stocks have been fully exploited and the change in stock abundance and availability of fish were caused by natural factors beyond human control.

4.7 Skipjack Tuna, *Katsuwonus pelamis* (Linnaeus)
"Katsuo"

(1) Distribution

Skipjack tuna is one of the "cosmopolitan" species distributed widely over the world's oceans. The habitat extends from the tropics to temperate zones, between 40°N and 40°S. The species is also characterized by its highly migratory nature.

(2) Population structure

In the Pacific Ocean, the fish occurs right across the zone mentioned above without any interruption from west to east and north to south. Because of its extremely wide distribution (both fish and spawning ground), highly migratory nature and ecological complexities, no consensus has yet been reached with regard to its population structure in the Pacific. Hypotheses on a single stock, two stocks and a combination of multiple local stocks have been proposed. However, it has been generally accepted by scientists that with the fish in the western Pacific should be dealt with as one group (Figure 16).

(3) Spawning

The spawning of the West Pacific group mentioned above takes place all the year round across a wide area, as shown in Figure 16. However, the concentration of larvae is restricted to waters with surface temperatures of 25°C and above.

(4) Early life form

Early life form from the larval stage to the stage of recruitment to the exploitation stock is not yet known.

(5) Growth

The growth rate is very fast but varies greatly by specimen, area and local group/school. A number of estimates and hypotheses on the growth rate have therefore been proposed. However, it is thought that the average body length (BL) at the beginning of each age of the fish in the region is around 15 cm at age-1, 45 cm age-2, 63 cm age-3, 73 cm age-4, and 77 cm age-5.

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[1] This method is highly efficient for catching saury and was introduced into the fishery around 1950 almost completely taking over the drift gillnet fishing employed previously.

[2] Fishing has been prohibited in Japan during January to July to protect major spawning in the south.

[3] Catches taken mostly by drift gillnets before, producing about 10-40 000 tons annually, were also subject to large fluctuations.

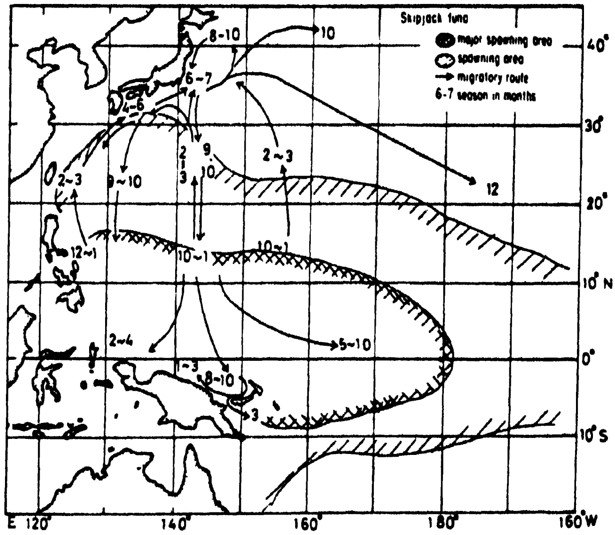

Figure 16 Spawning area and migratory pattern of skipjack tuna in the western Pacific Ocean.

(6) Migration

The migratory pattern of the fish is also highly complicated and variable, and the entire picture is not yet well understood. However, there is no doubt that most of the fish in the waters around Japan are part of the huge stock, originating further south and annually migrating into the region, forming numerous schools for feeding during spring and autumn (Figure 16). The fish move out of the region during winter and move down to the tropics for wintering and spawning. The migratory route and swarming conditions during their stay in the region are therefore greatly affected by changes in oceanographic conditions, especially those of the Kuroshio, Oyashio and the water fronts formed by the two. This is one of the key issues to be taken into account in the fisheries forecasting for skipjack tuna fishing in the region. However, several small local stocks remain in the region even in winter, especially in the waters along the Ryukyu/Nansei-shoto archipelago and Izu-Bonin (Ogasawara) Islands, which support sparse but continuous skipjack fishing in winter. The relationship between these local and migratory stocks is not yet known.

(7) Feeding habits and predators

Skipjack tuna, like other tunas, occupy a high trophic level and the adult fish are apparently piscivorous, feeding intensively on other fish species, especially on coastal pelagic fish during their stay in the coastal waters around Japan. Major food items in the region include sardine, anchovy, chub mackerel, Jack mackerel, saury and Japanese flying squid. However, at the same time, skipjack is an important food items for the larger piscivorous fish such as larger tunas and billfishes. Feeding habits from early life to the juvenile stage are not yet known.

(8) Fisheries

The majority of the catch in the region has been taken by pole-and-line fishing, accounting for about 70 percent of the total, followed by large- to medium-size purse seine, about 20 percent (Table 3). The fishing ground in the region moves seasonally from the southwest to northeast along the Pacific coast of Japan, as the fish migrate (Figure 16).

(9) Production

The total production during the past decade has been fairly stable, ranging from 100 to 150 000 tons annually (Table 4). The fish available to the fishery in the region seem to have been fully exploited since around 1960. A substantial increase in the catch cannot therefore be expected in the future even if greater effort is expended. At the same time, no sign of a decline in the entire stock abundance has been observed so far. The fluctuations in the total production would have therefore been caused chiefly by fluctuations in the availability of the fish in the region and success or failure in fishing, including locating the fish schools. This is why fisheries forecasting is so important to skipjack fishing in the region.

4.8 Japanese Flying Squid, Todarodes pacificus (Steenstrup) (Common squid), "Surume-ika"

(1) Distribution

Japanese flying squid are widely distributed in both warm and cold waters around Japan. Thus they are abundant in the eastern East China Sea, waters along the southeast and west coast of Japan where the warm Kuroshio and Tsushima Warm Current prevail, while they are also abundant in the Okhotsk Sea, the waters along the Kuril Islands to the northeastern coast of Japan and the north to western Japan Sea where the cold Oyashio and Liman Current prevail (Figure 17). This clearly shows the extremely eurythermal nature of the squid.

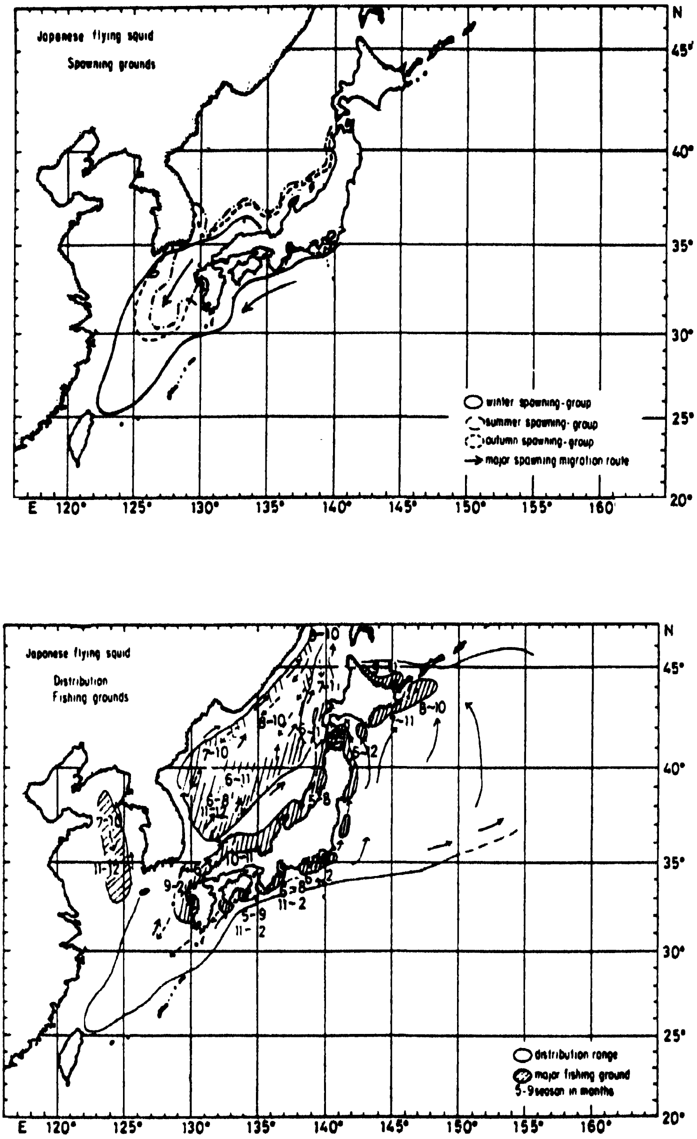

Figure 17 Spawning areas by spawning group, distribution range, major fishing grounds and seasons of Japanese flying squid. Major spawning seasons by group are: January-March for the winter group, (2) June-August for the summer group and (3) September-December for the autumn group.

(2) Population structure

A proper classification of the stocks of Japanese flying squid has not yet been made. However, they are composed of three different spawning groups; these are the (i) winter, (ii) summer and

(iii) autumn groups, with a different life cycle but with the same habitat. It is uncertain whether the successive two groups mix or remain separate. It is therefore, not possible at present to describe each of these groups as an independent stock.

(3) Spawning

Spawning takes place during January to March for the winter group, June to August for the summer group and September to December for the autumn group. The major spawning grounds of these three groups are located in almost the same area, extending from the eastern East China Sea to the south and western coasts of Japan along both the Pacific and the Japan Sea coasts (Figure 17).

(4) Early life form

Hatching usually takes four to five days in water temperatures of 14-21°C, releasing larvae of 0.7-1.0 mm in mantle length (ML). Larvae smaller than 15 mm ML are distributed from the surface to mid-layer of the sea, but concentrations are often found in a 25-50 m layer. They do not shoal or swarm until they grow to juveniles of 4-5 cm ML. Much about early survival is not known but it is presumed to be substantial, accompanied by large fluctuations caused by annual changes in both physical and biological conditions (predatory loss, etc.).

(5) Growth

Flying squid is a fast growing species with a very short lifespan, only one year. The average monthly growth rate is estimated to be about 3.5 cm for the first 6 months and 2.4 cm for the last 6 months. The average mantle length (ML) is estimated to be 7-8 cm at 2-months, 14-15 cm 4 months, 17-18 cm 6-months, 20-21 cm 8-months, 22-23 cm 10-months and 23-24 cm 12 months. The maturing body size is about 20 cm ML. All the squid die off after the first spawning at around 12 months old, when ML is about 24 cm.

(6) Migration

The squid migrate some distance to the north during spring to summer and to the south during autumn to winter. The winter group, which has attained the largest biomass among the three groups, begins northward migration in spring along both the Pacific and Japan Sea coasts of Japan, reaches the waters around the northern Hokkaido and the southern Kuril Islands in summer, the northernmost fringe of the distribution range, then returns to the south in autumn for spawning. Moving speed is supposed to be very fast, generally about 10 miles and occasionally 35 miles a day. This must be taken into account for forecasting purposes. The summer and autumn groups follow a similar migratory pattern although the season and the range of displacement are different. In the course of this migration, the squid encounters various changes in oceanographic conditions which affect greatly their migratory route and shoaling, and eventually their availability to the fishery.

(7) Feeding habits and predators

Although flying squid feed mostly on zooplanktons during the larval stage, they rapidly attain an omnivorous nature in accordance with their growth. The juveniles and adults feed greedily on various items encountered within their sight including larger zooplanktons, various smaller fish (both pelagic and demersal species) and squids (cannibalism has not yet been confirmed). Throughout its life the squid is an important food item for various carnivorous animals including mackerels, amberjack, tunas, billfish, sharks and marine mammals.

(8) Fisheries

The majority (about 90 percent) of the catch has been taken by light lured squid jigging with artificial bait-hook, taking full advantage of the greedy feeding habit and strong phototaxis of the squid (Table 3). The fishing ground along the Pacific coast is practically confined to the coastal zone, while that of the Japan Sea extends further offshore zone and is populated chiefly by the autumn group (Figure 17).

(9) Production

The annual catch during the past decade has fluctuated between about 200 and 300 000 tons. This is a considerable drop from 300 to 500 000 tons during 1955 to 1975. The decline has resulted mostly from the decline in the stock abundance of winter group squid. This change has not yet been fully explained. It is true that fishing increased greatly when various modern fishing techniques were introduced into the fishery during the 1950's to 60's, which undoubtedly contributed to the greater catches as mentioned above. However, there has been no clear sign of overfishing observed so far, neither has any sign of a recovery yet been observed, in spite of a substantial reduction in fishing intensity during the past decade. These may indicate that the major causes of the decline in the entire stock would have been mostly natural, rather than a result of fishing. Leaving aside the cause of the change in stock abundance, all the stocks in the region have probably been fully exploited.

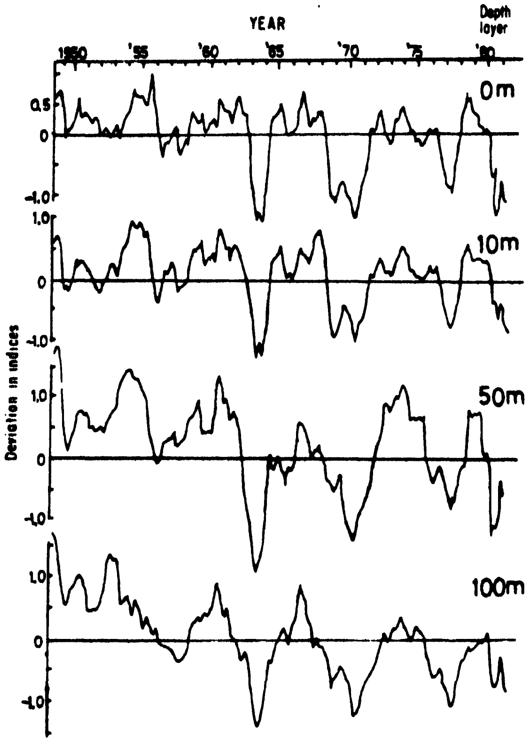

Figure 18 Deviation of monthly average water temperature of the Tsushima Warm Current from a secular mean by depth layer observed at the fixed station in the Eastern Korea Strait during 1948 to 1981 (Inoue, 1981).

5. METHODOLOGY OF FORECASTING

5.1 Oceanographic Factors

5.1.1 General background

Over the long history of ocean science, an analytical and theoretical method has been well developed for forecasting physical parameters of the sea. For instance, forecasts of changes in sea currents and water temperatures are generally made using various analytical studies in the fields of hydro- and thermo-dynamics, which include the analysis of the movement and displacement of a water mass, confrontation with and/or mixing of different water masses, etc. However, many factors are still not well understood and their functions have therefore not yet been fully taken into account. Thus the predictions derived from sophisticated and well formulated differential equations sometimes differ from the changes which actually occur in the sea, the situation is frequently paralleled in weather forecasting.

Another conventional method is a statistical analysis of the data on the phenomena actually observed in the past. Here, the accumulation of accurate records on various oceanographic conditions over a long period of time is necessary. Through careful examination of these data several oceanographic features inherent in a specific current or a water mass can be identified. Relationships and correlations between various parameters and sea conditions are accordingly estimated as outcomes of these exercises. These parameters enable us to extrapolate trends in physical conditions of the sea from current observations to predict their probable changes in the future. One of the advantages of this method is that the statistical cofidence interval can be given to each of the estimated parameters under a selected probability, which allows projection within a certain range. However, a few disadvantages involved in this method are: the (i) lack of a firm logical connection between observed and projected conditions and (ii) inaccuracy of the estimates caused by biases and/or noises involved in the original data employed.

Whichever of the above two methods is applied, analytical or statistical, some of the sea conditions are difficult to treat as numerical variables, e.g. a complicated meandering pattern of a sea current. An empirical projection method is frequently employed for such a case. In order to apply this method a large number of case studies on various phenomena are required as important background knowledge, and these studies need to be carried out by experienced oceanographers. It is generally not possible to store or process such information in a modern tool like a computer as the results derived from the studies are not machine-readable. The method, although not completely logical, works out well in many cases which are beyond the application of a logical and machine-readable method. This again resembles the method employed in weather forecasting.

5.1.2 Techniques employed

There is, then, no single standardized forecasting method. Instead, a combination of methods has generally been employed. The components of the combination vary from one case to another. These components are summarized as follows.

(1) Correlations

Relations of cause and effect are estimated between various parameters. These include both the bivariate- and multivariate-regression analyses. A combination of variables needs to be selected carefully according to the specific case to be examined, especially in a multivariate analysis. The oceanographers concerned must have a comprehensive knowledge of both oceanography and features of the waters in question to select adequate parameters to be employed.

(2) Periodicity

When a repetitious phenomenon is observed, the periodicity of the occurrence is examined employing various analyses of the observed time series data. These include correlogram, harmonic and spectrum analyses. However, periodicity in oceanographic conditions varies greatly in nature. A flexible and careful approach is required in the application of these analyses to the forecasts and in the interpretation of the results obtained.

(3) Similarity

This is one of the empirical methods mentioned previously, in which an analogy or analogies is/are applied to the projection when a similarity is observed to the change in trend or to the occurrence of a specific condition. This has sometimes worked out well for non-numerable phenomena, e.g. location or shape of a specific water mass.

(4) Persistency

This can be derived from either or both statistical and empirical methods. If numerable information is available for the condition to be examined, a "run's test"[1] or other statistical test can be applied to predict the persistency of the phenomenon.

(5) Trend

Prediction of the trend in a specific phenomenon is often very useful for forecasting changes in sea conditions in the immediate future. This can be done by either statistical or empirical methods, or by both. The latter implies the application of a simple extrapolation, which has been commonly employed in many cases regardless of the logical or theoretical features involved in the phenomena.

(6) Relationship to meteorological factors

The influence of climate upon a sea condition is sometimes very important, especially in short-term forecasting. The major factors to be taken into account are wind (direction and force), air temperature, rainfall and atmospheric pressure. The analyses are made by linking oceanographic and meteorological methodologies together.

5.1.3 Examples

(1) Japan Sea

The long-term record of the changes in water temperature in the Japan Sea gives a good example of the periodicity and persistency of an oceanographic condition. The general pattern of the changes is summarized as follows:

1/ A statistical test for a "run", which is the occurrence of an uninterrupted series of the same attribute in a series of observations.

(i) anomalies in water temperature at the surface of the sea, both warmer and cooler than the average, usually last for about two years;

(ii) anomalies in water temperature at 50 m depth in the Tsushima Warm Current persist only for about two months;

(iii) periodicity of anomalies in the monthly temperature at 50 m depth along the Japanese coast appears usually every 6.5 or 7 months (or integer multiples of these);

(iv) a six-year periodicity is consistently observed in the divergence from mean temperature at 50 m depth in the offshore waters of Japan, up to 80 miles distance from the coast;

(v) a distinctive periodicity is observed in the annual mean temperature in the Eastern Korea Strait with 6.5 and 8.8 year cycles at 50 m depth.

Figure 18 shows deviations in monthly average water temperature from a secular mean in the Tsushima Warm Current by depth layer during 1948 to 1982, which shows clearly the periodicity and persistency mentioned above.

Forecasting the pattern of the Tsushima Warm Current over the following fishing season is extremely important as it affects greatly oceanographic conditions and ultimately fishing conditions in the entire Japan Sea. Gathering data on the phenomena mentioned above is a major part of oceanographic forecasting in the region.

(2) Pacific Ocean adjacent to southern Japan

The dynamic change in the Kuroshio plays an important role in the change of oceanographic conditions in the region, similar to the role of the Tsushima Warm Current in the Japan Sea. The flow of the Kuroshio can be classified into five general patterns as shown in Figure 19. Type-I is a fairly stable pattern that persists usually from 2 to 9 years, but the other are not.

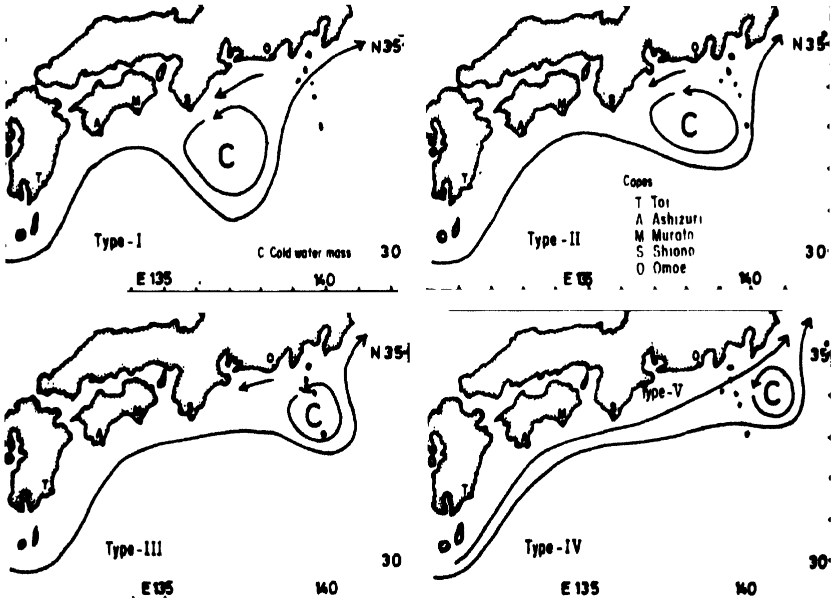

Figure 19 Schematic illustration of different meandering patterns of the Kuroshio, with a cold water mass formed and trapped by each (Nitani, 1969).

When the Kuroshio is in an unstable phase, the pattern of the flow usually changes from Type-V (no meandering) to Types-II, III, IV and V in turn. The stable phase, Type-I, often occurs when the flow shifts its main axis for some reasons, and turns well away from the coast at around the south-east coast of Kyushu Island. A large cold water mass ("C" in Figure 19, Type-I) is formed in this case in the east, inside the meander, which usually extends further east afterwards. A strong westerly counter current is developed along the southern coast of the Honshu when Type-I has stabilized. The distance of the main axis of the Kuroshio from the southern coast of Japan changes cyclically. Figure 20 shows such changes observed at five major observatory capes along the coast (see Figure 19 for the location of these capes). The Figure also shows forecasted future distances which have been derived from the observed data by means of harmonic analysis. The analysis has been integrated into a prediction of the pattern of the Kuroshio's future flow by means of the estimated distances of its main axis from the major capes along the coast. Figure 21 shows some of these trials.

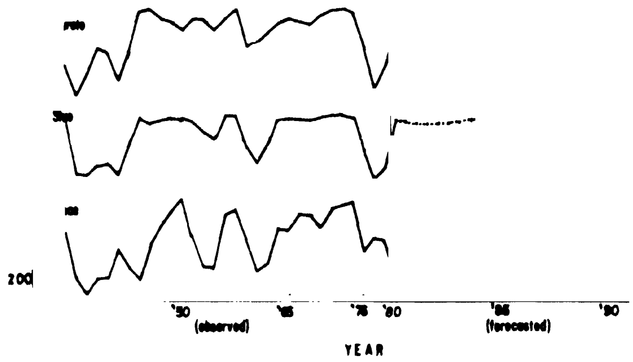

Figure 20 Observed and estimated distance of the main axis of the Kuroshio at selected major obsrvatory capes (Miyata *et al.*, 1981).

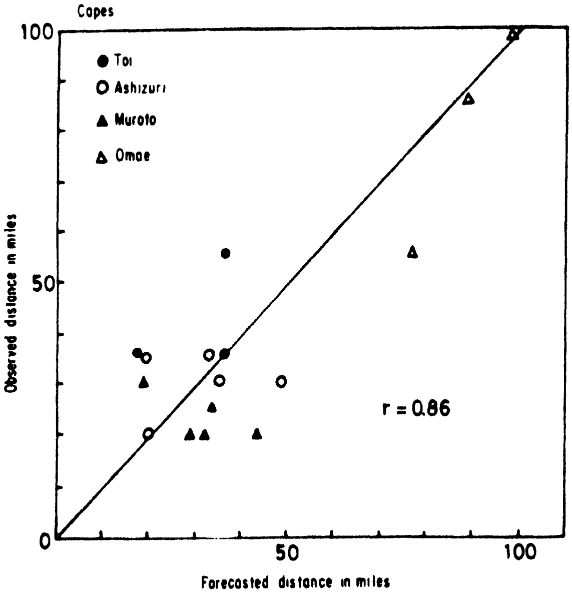

Figure 21 Comparison between the forecasted and observed distances of the axis of the Kuroshio from selected observatory capes during October 1974 to February 1975 (Miyata *et al.*, 1981).

(3) Pacific Ocean along northern Japan

The latitudinal position of the northernmost fringe of the Kuroshio fluctuates seasonally to north and south as shown in Figure 22. However, the annual average position of the fringe shows a periodical shift every 4 to 5 years.

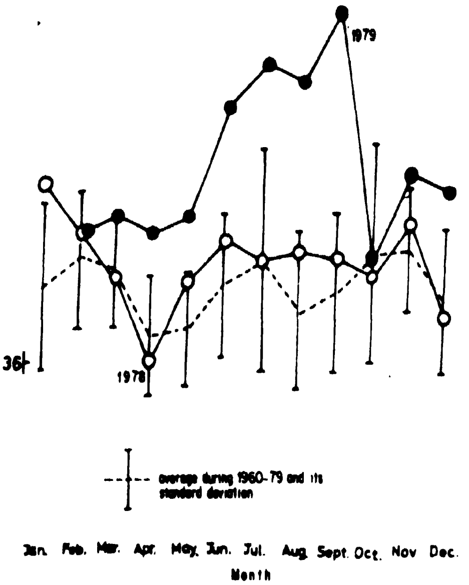

Figure 22 Seasonal and annual fluctuation in latitudinal position of the northernmost fringe of the Kuroshio along the north-eastern Pacific coast of Japan (Tohoku Regional Fisheries Research Laboratory, 1981).

A number of warm water masses are created by the Kuroshio around the sharply bending part. The larger ones are usually formed during winter to spring, and the medium and smaller ones during early summer and autumn. They move mostly northward, sometimes east and westward, but rarely southward. The larger ones are usually located in the offshore waters along the east coast of the Honshu or the southeast coast of the Hokkaido. They are stable in nature, usually persisting for several months with water temperatures remaining stable at the centre of those masses.

The strength of flow of the Oyashio in the region changes periodically every 9 years and it changes seasonally too. The intrusion of one of its branches into southern coastal waters is generally strongest in spring and weakest in autumn. In contrast, the intrusion of another branch into offshore waters is stronger in the later half of the year. However, the seasonality and magnitude of these Oyashio extensions vary considerably compared with those of the Kuroshio.

The outflow of the Tsushima Warm Current into the Pacific Ocean from the Japan Sea through the Tsugaru Strait is weakest in winter and strongest in summer and autumn. The strength of the current also varies cyclically, every 7 years.

When forecasting oceanographic conditions in the region all the above mentioned features need to be taken into account.

5.2 Fishing Conditions

The term "fishing conditions" is traditionally and frequently referred to in Japan to express a complex of various natural elements involved in fishing operations. Most other countries do not have their own equivalent of this concept. A good idea of what it means can be gained if one considers the "availability plus catchability" in terms of resources assessment terminology. It includes, therefore, formation of fishing ground and season, ease/difficulty of locating fish, abundance and density of exploitable stocks, migration and displacement of fish, size and number of fish schools and several specific biological characteristics of interest to fisheries such as body size, maturity and fatness of the fish, etc. The relationship between forecasting fishing conditions and marine biology is very much like that between forecasting oceanographic conditions and oceanography.

5.2.1 Long-term forecasting

The long-term forecast referred to here aims at forecasting at least several months in advance. It sometimes covers the fishing season for the whole year and occasionally for a few more years. The basic method employed is the same as that of general resources assessment. Namely, magnitude and timing of spawning, survival rate during early life period, size and timing of recruitment, growth and age structure, and magnitude of natural and fishing mortalities are the major parameters that have to be taken into account. However, the method involves a few inevitable disadvantages, e.g. its weakness in identifying the exact location of fishing grounds, and the length of time required to collect, process and analyse the data. In addition, some specific biological characteristics hamper the effective application of the method. For instance, many coastal pelagic fish fisheries depend upon recruitment for most of the catchable stock, and the fluctuation in recruitment size is sometimes quite large owing to unknown factors, which sometimes make stock assessment unpredictable and valueless for immediate industrial purposes.

Several supplementary methods are usually applied to these stocks, including an acoustic survey method for quick assessment, statistical and empirical methods mentioned in the earlier part of this section (5.1.2), etc. For instance, data on eggs and larvae collected by the spawning survey sometimes enable the biologist to predict the magnitude of forthcoming recruitment by correlation and/or extrapolation methods.

In short, when forecasting long-term fishing conditions, careful procedure using a combination of various methods is required, as when forecasting oceanographic conditions.

5.2.2 Short-term forecasting

Short-term forecasting aims at predicting fishing conditions in the immediate future, over a period of one or two weeks. The most important aspects of this forecasting are the prediction of the changes in fishing grounds, abundance and density of exploitable stock, any of which provoke the keenest interest in fishermen.

Information employed in short-term forecasting is therefore oceanographically rather than biologically oriented. The data obtained from satellite imagery is extremely useful in terms of its wide coverage and speed in arrival. The real-time record of fishing operations (day-to-day fishing log) also provides very important information for this type of forecasting. These are the reasons why the JFIC expends considerable effort in collecting and processing real-time data, which includes not only fishing logs but also the data collected by experimental and exploratory fishing and aerial surveys (see section 2.5).

It is noted, in contrast to the above, that the statistical method has not been widely used in short-term forecasting as random noises involved in the statistical data often mask slight changes occurring in the sea and fish stocks.

Empirical methods are, however, often employed by both institutes and fishermen, especially by the latter. Readers are all well aware of how talented fishermen are at using their sixth sense to make a good catch.

5.3 Forecasting by Species

The authors present here the practical aspects of forecasting employed for each of the eight target species. First, forecasting for Japanese sardine is described in detail. Many of the principal techniques commonly applied are included here. The procedures for the other species are then presented one by one with emphasis on species-specific features, avoiding repetitive descriptions of the items that have to be taken into account for each species.

Figure 23 shows the flow of data processing and studies employed generally in the spawning survey for assessment and long-term forecasting purposes for major coastal pelagic fish around Japan. For skipjack tuna and Japanese flying squid different surveys and methods are employed as the spawning ground is in tropical waters for the former species and peculiar species-specific features are involved in the latter, e.g. annual lifespan, etc.

5.3.1 Japanese sardine

The case of the Pacific sub-population is taken as an example since it covers the widest area and has most elements to be taken into account.

(1) Long-term forecast

(1) Elements of forecast

Location of fishing ground, duration of fishing season, fish size, abundance of exploitable stock and probable total catch.

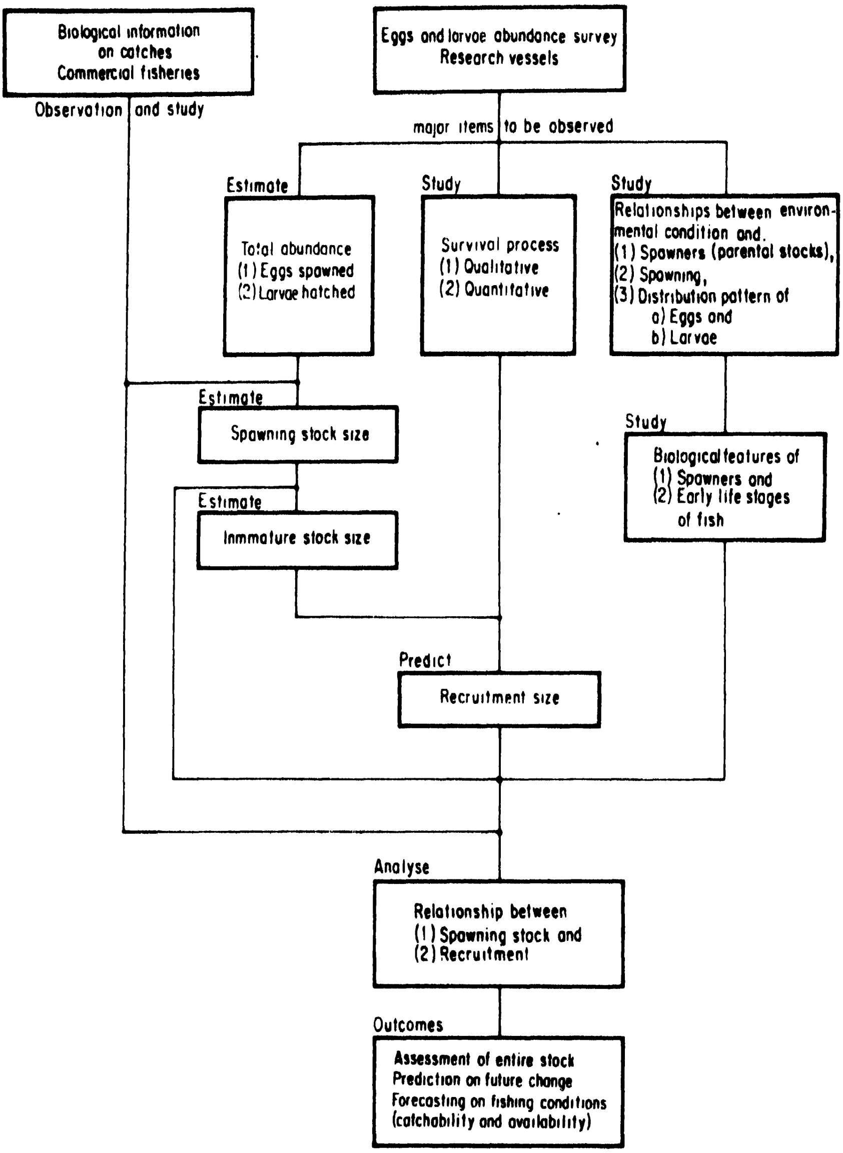
Biological information on catches Commercial fisheries
Observation and study
Eggs and larvae abundance survey Research vessels
major items to be observed
Estimate
Total abundance (1) Eggs spawned (2) Larvae hatched
Study
Survival process (1) Qualitative (2) Quantitative
Study
Relationships between environmental condition and. (1) Spawners (parental stocks), (2) Spawning, (3) Distribution pattern of a) Eggs and b) Larvae
Estimate
Spawning stock size
Study
Biological features of (1) Spawners and (2) Early life stages of fish
Estimate
Inmmature stock size
Predict
Recruitment size
Analyse
Relationship between (1) Spawning stock and (2) Recruitment
Outcomes
Assessment of entire stock
Prediction on future change
Forecasting on fishing conditions (catchability and availability)

Figure 23 Process flow employed in the spawning/eggs/larvae survey of major coastal pelagic fish stocks around Japan for stock assessment and fisheries forecasting purposes.

(2) Frequency and timing

Regularly three times a year: March, July and December.

(3) Basic knowledge required

(a) Relationship between fish behaviour and water temperature, especially with regard to spawning of parental stock and seasonal migration for both spawning and feeding (see section 4.1).

(b) Position and course of the Kuroshio and Oyashio, distribution pattern and movements of various water masses along these two major currents, location and pattern of water front formed by the two currents (see section 5.1.3, items (2) and (3)).

(c) Distribution range of the stock and changes in accordance with changes in stock abundance.

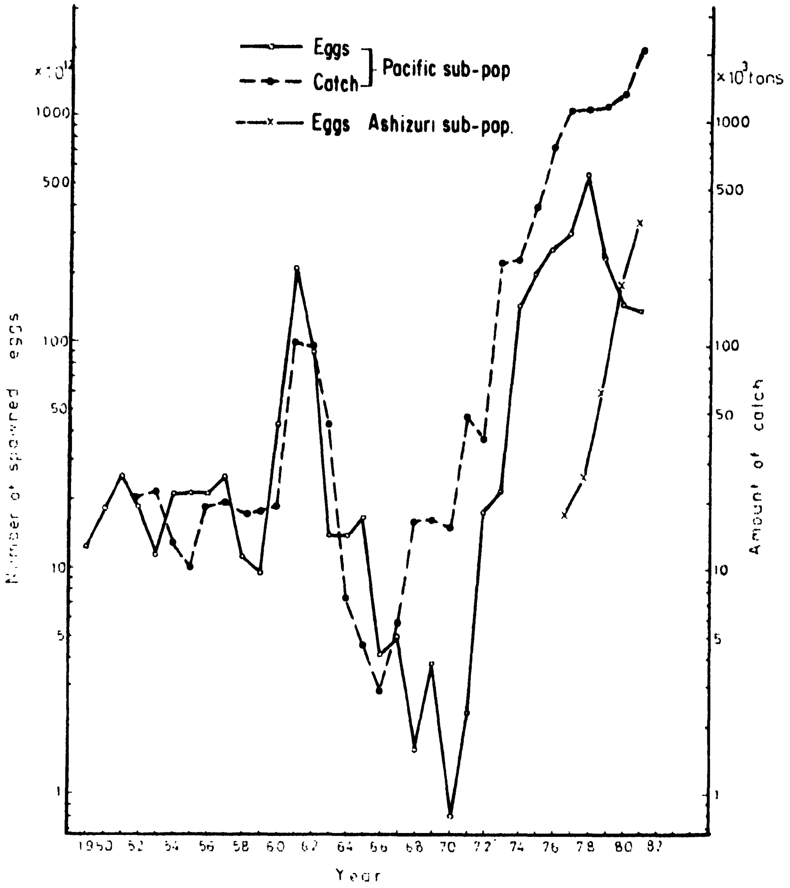

Figure 24 Annual change in the estimated total number of eggs spawned and the nominal catch of the Pacific sub-population of Japanese sardine during 1949 to 1981. The change in the former in the Ashizuri sub-population is also shown for 1977 to 1981 (Nakai, 1962, Watanabe et al., 1979).

(d) Spawning prediction estimated from the amount of current catch (see Figure 23).

(e) Magnitude of a new year-class strength estimated from the above.

(f) Relationship between the above and the relative abundance of the entire stock (age-structure).

(g) Relationship between the amount of the "shirasu" catch (post-larvae) along the central Pacific coast of the Honshu and the meandering pattern of the Kuroshio in offshore waters (see section 5.1.3, item (2) and Figure 19), which is the key to predicting the abundance and availability of juvenile and adult fish along the coast a few months later.

(4) Essential data employed

(a) Data on sea currents and distribution pattern of water masses.

(b) Amount of eggs spawned, number of larvae hatched and their distribution pattern.

(c) Catch per unit effort (catch rate and geographic distribution pattern of the catch), biological parameters of the catch (size/age composition, maturity and fatness, etc.).

(5) An example of forecasting

The example below is a forecast made for the fishing season August to October 1982. It was released in July 1982, just before the season.

(a) Key factors taken into account specifically for the forecasting season

Fishing season and ground

(i) The meandering patterns of Types-II and III of the Kuroshio take place alternately for about a 2 to 3 months each (see Figure 19). The branches of the Kuroshio extension reach further north than in average years.

(ii) Intrusion of the Oyashio extensions into southern waters has remained strong since the previous year (see Figure 6).

(iii) The water temperature in the coastal zone between the Kuroshio and the coast is generally normal.

(iv) Substantial amounts of large- and medium-size sardine have been incidentally caught by salmon gillnet fishing in northern waters off the Hokkaido, in June.

(v) An overall assumption derived from the above: the basic distribution and migratory pattern of the fish will be almost identical with those in normal years.

Abundance, age and size structure of the fish

(vi) The 1980 year-class dominated in the catch as age-1 fish during 1981, while the 1979 and 1981 year-classes appeared to have been rather weak.

(vii) The growth of the 1980 year-class was slow, probably owing to density dependent factors caused by high abundance. As a result, the fish will not start spawning at age-2 this year, in contrast to the norm.

(viii) The 1980 year-class has remained fairly abundant even in this fishing season and will contribute the majority of the catch.

(b) Forecast made

a) East coast of Hokkaido

(i) The catch from the region will depend mostly on the many feeding adult fish schools migrating north along the coast.

(ii) The fishing season will extend until October. The fishing ground will be formed along a 200 m deep bathymetric zone, but it will move southward toward the end of the season. The daily catch rate during the season will be fairly stable.

(iii) The dominant year-classes and fish sizes are age-4 with 19-21 cm BL (body length) at the beginning of the season and age-2 with 17-18 cm BL in July. The fish age-1 with 14-15 cm BL will join the dominant group after August.

(iv) The total amount of the catch to be taken by purse seine in the region will be nearly equivalent to, or slightly smaller than, that of 1981, ranging between 600 to 700 000 tons.

b) Northern coast of the Honshu

(i) The fishing will depend mostly on the many feeding adult fish schools migrating northward along the coast. The fishing season will start in August and end in November. The fishing ground will be formed in the coastal zone in the region.

(ii) The dominant year-classes in these schools will be age-2 and age-1 with 14-18 cm body length.

(iii) The total amount of the catch to be taken by purse seine will be around 100 000 tons, or slightly more. The catch taken by coastal setnet, which includes the catch of age-0 fish, will be nearly equivalent to those in recent years.

c) Central coast of the Honshu

There are three major fish groups to be exploited in the region.

(i) Fish migrating northward

- The fishing currently undertaken in the region will end in early August, earlier than in 1981. The fishing ground will remain in the coastal zone throughout the season.
- The dominant year-class in the catch will be age-2. The total amount of the catch from this group will exceed the average annual catch in recent years.

(ii) Fish remaining in the region during summer

- The major fishing season will be from late August to late September. The major fishing ground will be formed first around the Cape "Inubo" (the easternmost tip of the central Honshu, around 36°N). The ground, however, will rapidly spread northward as far as the "Sendai" Bay (around 38°N).
- The dominant year-class will be age-1 and the total catch from this group will be at nearly average level for recent years.

(iii) Fish migrating southward

- The fishing season will be from mid-October to December, which is substantially shorter than in 1981. The fishing ground will be formed first along the central coast, but it will gradually shift southward as the season progresses.
- The majority of the catch will be composed of fish age-2 and 1. The total catch from this group will probably be slightly above 200 000 tons.

(d) Southern coast of the Honshu

(i) Fishing depends mostly on the fish migrating northward along the coast.

(ii) The fishing season will be from July to September in the northern region and from July to November in the southern region.

(iii) The catch will be almost exclusively composed of age-0 fish with 6-12 cm BL. The total catch will not reach 50 000 tons, as usual in recent years.

(2) Short-term forecasting

The short-term forecast for Japanese sardine aims chiefly to predict the changes in fishing conditions in the immediate future. It is usually made every week, two weeks and month (see sections 2.2.2, 5.2.2 and Figures 4-A and 4-B). In addition to the factors generally employed, the following were specifically taken into account for the forecasts made in 1982.

(1) East coast of the Hokkaido

The location and pattern of water fronts determine first the water temperature and isotherm pattern around the front, and second the movement of the fish, which eventually determines the location of productive fishing grounds in the region. For instance, when the fish schools approach the coastal zone in July to August, they usually tend to move further north along warm waters of 10-15°C that have resulted from the northerly intrusion of the Kuroshio extension.

In contrast, an extension of the cold Oyashio usually intrudes into the coastal zone of the region during August and September. The fish, as a result, are forced to concentrate in the warm offshore waters bordering the western fringe of the water front during the season. This is the common pattern during the peak fishing season in the region.

The region is generally the northernmost fringe of the feeding migration of the Pacific sub-population. The fish are therefore fattest around the end of the fishing season.

(2) Northeast coast of the Honshu

Similarly to the above, the major fishing grounds are formed along the warmer part of the water front. In summer the surface water temperature is not always a good indicator of fishing ground, while in autumn it indicates the location of the grounds more clearly. A negative correlation is observed between the catch rate and the distance from the coast in this region, too.

Observation of water temperature by means of XBTs and the infra-red imagery of a satellite are extremely useful in terms of coverage of the area and the timeliness of detecting changes in oceanographic conditions.

5.3.2 Japanese anchovy

The procedure for forecasting Japanese anchovy is almost the same as that employed for Japanese sardine.

Japanese anchovy prefers more nearshore waters than sardine, being distributed abundantly in inshore waters, bays and inland seas, e.g. the Seto Inland Sea (see section 4.2 and Figure 10). The day-to-day fishing conditions are therefore very familiar to the coastal fishermen. For this reason, the short-term forecast is not made for Japanese anchovy.

5.3.3 Japanese chub mackerel (common mackerel)

Forecasting chub mackerel is rather similar to forecasting Japanese sardine. Both long- and short-term forecasts are made for the fish. A few species-specific features to be taken into account can be summarized as follows:

(1) Major habitat and spawning grounds are located further offshore than those of sardine (see section 4.3, Figures 9 and 11), which means that data and information on offshore waters are more important for forecasting chub mackerel;

(2) Lifespan is longer, fish size is larger and swimming speed (movement) is faster than those of sardine, which means that more biological information than for sardine is required for forecasting. This includes the magnitude of spawning, fecundity, growth rate, age/size structure and fatness, etc.;

(3) The fish do not appear to be displaced by changes in water temperature as easily as sardine. However, the rapid movement of the fish from one fishing ground to another appears to be associated with sudden or rapid changes in water temperature. This requires more real-time data on oceanographic conditions covering a wider area for forecasting. Satellite imagery is extremely useful in this regard, especially for short-term forecasting.

5.3.4 Japanese Jack mackerel

The main components of forecasting method are the same as those for sardine. However, the quantity of information available for forecasting purposes has been limited in recent years owing to sparse fishing resulting from a drastic decline in stock abundance, especially in the migratory stocks originating from the eastern East China Sea (see section 4.4 and Figure 12). A substantial part of recent catches appears to have been made up of many sedentary local stocks (see section 4.4, item (6)). Because of the circumstances, forecasting Jack mackerel in recent years has concentrated on comparing the catch rates observed in various fishing grounds rather than employing biological and oceanographic information.

(1) Long-term forecasting (an example)

The following is an example of a forecast Jack mackerel, covering the 1982 fishing season, April to September. It was issued in March 1982.

- The major fishing grounds will be formed around (i) the "Goto" Islands (west of the Kyushu Island), (ii) the eastern-central and (iii) southern East China Sea.
- The majority of the catch from these grounds will be composed of young and small fish. The total amount of the catch will be nearly the same as, or slightly more, than last year.
- The catch from the coastal waters of western Japan will be slightly better than last year.

(2) Short-term forecasting

Short-term forecasting has so far been carried out only for coastal waters in the Japan Sea for the reasons given above. The major elements specifically taken into account are: the (i) distribution and migratory pattern of age-0 and age-1 fish along the western Japanese coast and (ii) oceanographic conditions in the coastal zone, specifically associated with changes in the Tsushima Warm Current (see section 3.3 and Figure 7).

5.3.5 Japanese amberjack (yellowtail)

Only long-term forecasting has been applied for this fish. Major information employed is: (i) catch rate and gear used, (ii) size and age structure of the catch and (iii) oceanographic conditions. However, systematic forecasting of the probable amount catch has not been made owing to the difficulties of prediction, arising chiefly from the highly complicated ecological features of the fish (see section 4.5 and Figure 13).

5.3.6 Pacific saury

Forecasting Pacific saury is traditionally very important to Japanese fishermen. Among various reasons the (i) large quantity of the catch with high commercial value, (ii) large annual fluctuation in availability and (iii) long-range and very rapid seasonal migration have inter alia made the demand for forecasting of this fish strongest (see section 4.6 and Figure 15). The method employed in forecasting saury is, therefore, somewhat different from those for the other neritic pelagic fish. Here we set out the details of forecasting the Northwest Pacific population along the Pacific coast of Japan, to give a typical example.

(1) Long-term forecast

(1) Elements of forecast

Location of fishing ground, fish size, amount of catch.

(2) Frequency and timing

Regularly twice a year: August and October. The fishing season starts in August and ends in December. Fishing for saury is prohibited during January to July in Japan (see section 4.6).

(3) Basic knowledge required

(a) Estimated abundance of larvae spawned during winter and spring. A clear positive correlation exists between the abundance of larvae and recruitment in early summer.

(b) Estimated abundance of saury by body size group during the pre- and early season, which usually correlates positively with the amount of catch for each size group.

(c) Total catch and catch rate of saury by coastal setnets, which generally reflect relative abundance of the entire stock migrating northward for feeding.

(d) Records of sighting of fish schools by body size group made by fishing vessels, which correlate well with the total catch for the season.

(e) Results of experimental fishing for juvenile saury carried out in offshore waters in April, which give a good indication of the abundance of exploitable stock about 5 months later. The fishing is carried out by salmon exploratory research vessels every year employing specifically designed small-mesh gillnets.

(f) Distribution and pattern of the Oyashio front throughout the fishing season, especially the isotherm structure. The fish first swim over the frontal zone and second cross the water front formed by extensions of both the Kuroshio and Oyashio when they approach the northernmost fringe of their migration. However, the pattern of the aggregation, displacement and dispersion of the fish in this particular zone varies greatly, being affected by variations in oceanographic structure there (see Figure 25).

(4) An example of a forecast made for the fishing season, August to December 1982
(The first regular forecast, released in August 1982)

(a) Key factors taken into account specifically for the forecasting season

(i) The Oyashio front in summer is located further north than that in a normal year.

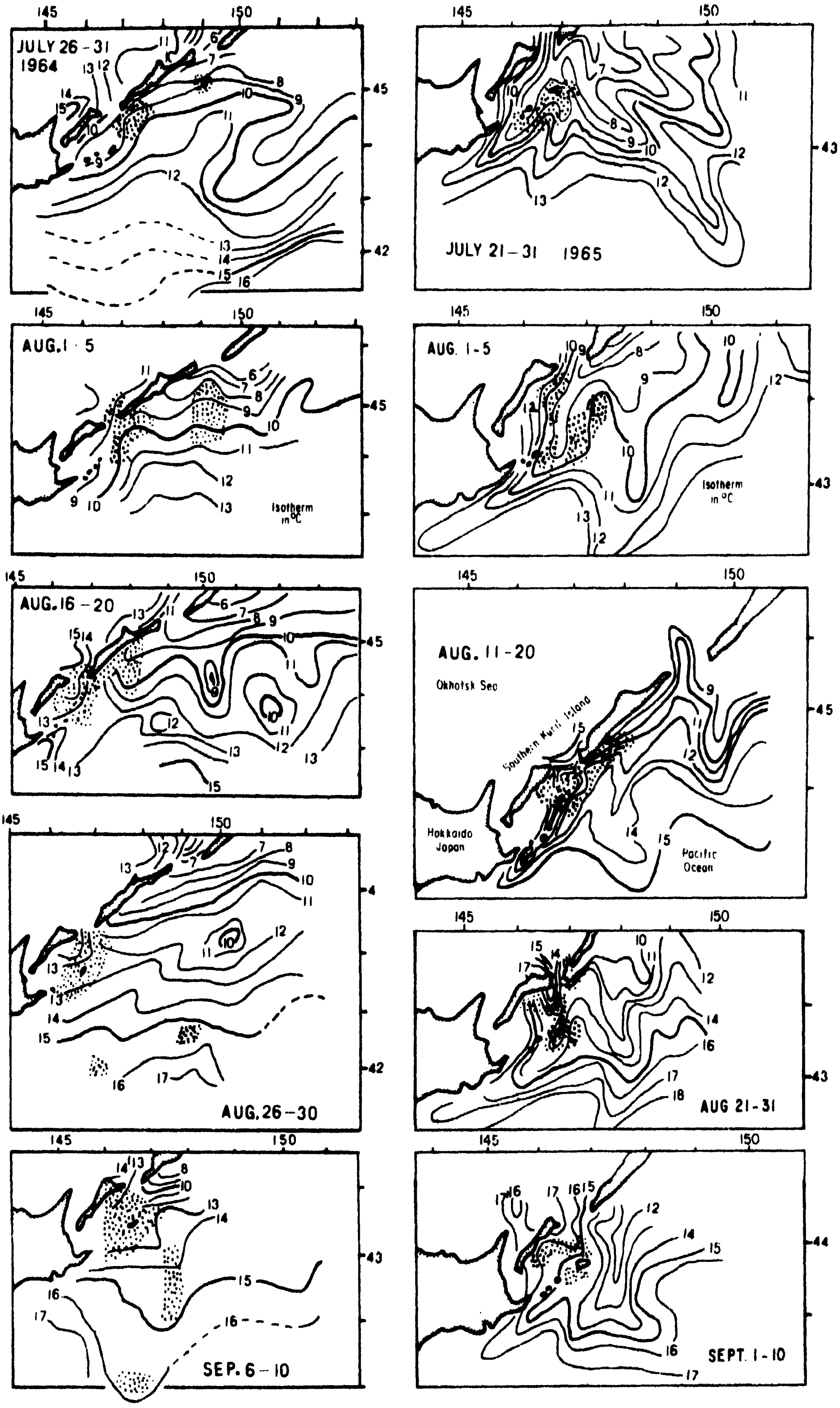

Figure 25 Relationship between the surface water isotherms and the formation of fishing grounds for Pacific saury (Hotta and Fukushima, 1970). The figures on the left are examples taken from a cool summer observed in 1964, showing rapid movements of fish schools, while the figures on the right from a hot summer in 1966, showing sedentary or slow moving fish schools.

(ii) The abundance of larvae during February to March is estimated to be lower than in an average year, but higher during April to May. This may indicate the high survival rate of the year class during its early life stages. Nevertheless the original abundance of hatched larvae may have been somewhat lower than in a usual year.

(iii) The result of the exploratory saury sampling survey in offshore waters (west of 150°E) carried out by the research vessels during April to May generally shows rather poor distribution of saury in that particular zone.

(iv) However, the experimental fishing carried out by salmon research vessels in further offshore waters (high seas around 160°E) in April indicates that saury is generally highly abundant, showing (a) the highest level in recent years for middle- and small-size fish groups and (b) the second highest for the large-size fish group.

(v) Catch of the fish migrating northward taken by various gears in coastal waters is unusually large.

(vi) The record of fish-school sightings made by commercial fishing vessels indicates that (a) fish schools are generally abundant in offshore waters rather than in the coastal zone, (b) middle-size schools are the most abundant probably exceeding that in a normal year, (c) which is followed by small-size schools but (d) large schools are very few.

(vii) The catch taken by small offshore fishing vessels in early August is pretty good, an encouraging opening to the season.

(viii) A warm water mass is located about 50 miles off the southeast coast of the Hokkaido. The coastal branch of the cold Oyashio extension runs down to around 37°N (a prominent intrusion down to about 70 miles north of the "Inubo" Cape, the easternmost tip of central Japan). The offshore branch of the Oyashio extension reaches as far south as 39.5°N.

(b) Forecast made

(i) Northward migrating season (August-October)

The two major fishing grounds will be formed around the Oyashio front: (a) one along the southern Kuril Islands and (b) another in the waters further south, where 10-15°C water temperatures prevail (see Figure 25).

The size of fish will be mainly large with some medium to small fish in the northern ground while they will be mostly medium to small in the southern ground.

(ii) Southward migrating season (October-December)

Fishing for southerly migrating fish will start in late August in the waters around the southern Kuril Islands and along the east coast of the Hokkaido.

The fish then migrate south separating into two groups, one moving to offshore waters and the other moving along the coastal zone. In September the fishing ground for the offshore group will be located in a zone between 40-42°N and 147-150°E (off the southeast Hokkaido, see Figures 4 and 6). The ground will move southwest toward and along the outer fringe of the warm water mass off the east coast of the northern Honshu (see (4)-(a)-(viii) in this section). The fishing ground for the coastal group will be formed firstly along the northern Honshu coast but will shift toward the south during the season.

(5) An example for the fishing season, October to December 1982
(The second regular forecast released in October 1982)

Amendments and modifications to the above were made with updated data and information acquired during the first half of the fishing season. The major points covered are summarized as follows:

(i) The offshore water temperature has remained unusually high, which has hindered southward migration of the coastal fish group.

(ii) This has also affected the offshore group by forcing fish schools to move further offshore and dispersing them over a wide area, thus decreasing the availability of fish. As a result, total production as of 6 October 1982 was only 47 percent of that during the same period in the previous year.

(iii) There are indications that oceanographic conditions will change soon favourably for fishing saury, especially in the waters along the southeast coast of the Hokkaido and the northeastern coast of the Honshu. However, it seems unlikely that the total amount of the catch will recover greatly as only a short period of this fishing season is left.

(iv) Total production for the entire season will thus be substantially lower than that estimated in the first forecast made in August, probably 200 000 tons at best.

(2) Short-term forecasting

Short-term forecasting has been intensively employed for saury fishing for the reasons mentioned at the beginning of this section. In addition to the parameters generally employed, the species specific features to be taken into account can be summarized as follows:

(1) Searching for the so-called "optimum temperature" (15-19°C) is not sufficient to predict where productive fishing grounds will probably form as saury react very sensitively to minute change in the thermal structure of their environment. For instance, the fish tend to aggregate in the optimum temperature waters where annual change in the surface temperature is less than 2°C.

(2) The aggregation pattern differs by fish-size group. Predictions on the location of fishing ground must take this into account.

(3) Southward migration is sometimes halted temporarily, especially when the horizontal gradient of thermal structure slackens, which results in sudden changes in fishing conditions.

(4) In addition to the location and movement of the Oyashio front, the appearance and movement of eddies accompanying the front also affect greatly the behaviour of the fish.

(5) Satellite imagery is extremely useful in tracing many of the above-mentioned oceanographic conditions on a real-time basis.

5.3.7 Skipjack tuna

Forecasting skipjack fishing is traditionally very important in the region as the fishing depends mostly on seasonal long-distance migratory fish (see section 4.7 and Figure 16).

(1) Long-term forecasting

(1) Elements of forecast

Major fishing ground during July to October (the fishing season in the region), relative abundance, size and age structure of the exploitable stock in the region.

(2) Frequency and timing

Regularly once a year, in June (just prior to the fishing season).

(3) Basic knowledge required

(a) The total catch taken in the region fluctuates considerably, generally increasing one year and decreasing the next (see, Table 4), which may reflect the annual change in overall availability of exploitable stock migrating into the region.

(b) The total catch correlates positively with the catch of age-1 fish taken in the southern tropical waters during the preceding year.

(c) The catch from the region has been mostly made up of fish of age-2 and partly age-3 and age-1. The overall age composition of the total catch for the whole season can be estimated from the catch taken in the southern Honshu at the beginning of the season.

(d) The most productive fishing grounds in the region are usually formed around the northernmost fringe of the warm water front.

(4) An example for the fishing season, July to October 1982 (released in June 1982)

(a) Key factors taken into account specifically for the forecasting season

(i) The intrusion of the Kuroshio extension into the coastal zone is fairly strong along 145°E. A distinguishable warm water mass exists around the intersection of 40°N and 145°E (south of the Hokkaido and east of the northern Honshu).

(ii) The offshore branch of the Oyashio reaches as far as 39°N and 148°E (about 100-150 miles southeast of the warm water mass mentioned above).

(iii) The coastal catch as of June was composed mostly of age-2 fish.

(b) Forecast made

(i) The northward migration will take place along two major routes, one 144-145°E in the coastal zone and the other 153-155°E in the offshore zone.

(ii) The most productive fishing grounds will be formed around the northernmost fringe of the Kuroshio extension in the offshore zone.

(iii) The catch will be composed nearly exclusively of age-2 fish with 43-44 cm body length.

(iv) The total catch from the entire region will be about 40-45 000 tons at least or 47-50 000 tons at most.

(2) Short-term forecasting

Information on the horizontal thermo structure of the surface layer of the region is the most effective for forecasting skipjack fishing on a short-term basis as migratory and aggregation patterns are strongly dependent upon temperature patterns on the surface of the sea. Figure 26 clearly shows this feature, which can be summarised as follows:

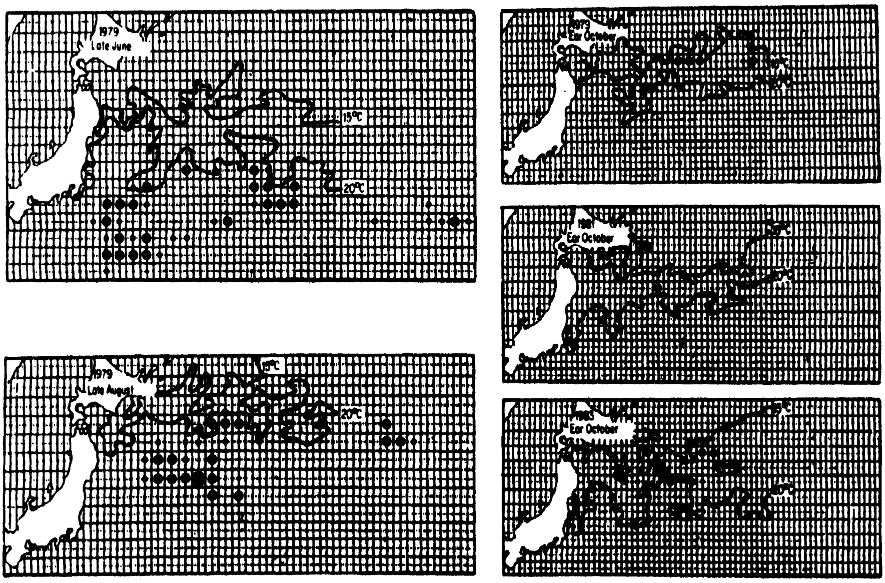

Figure 26 Relationship between the surface water isotherms and the formation of fishing grounds for skipjack tuna in offshore waters along the northeast coast of Japan (Iizuka and Asano, in preparation).

(1) In May and June the major fishing ground is formed south of the trough in the 20°C isotherm of surface temperature, around 36-37°N.

(2) In August fish schools move further north in accordance with the northerly shift of the trough mentioned above and stay mainly in 38-43°N latitudinal waters.

(3) In September the fish still remain in waters around 40°N where surface temperature has decreased to 15-20°C. This is the beginning of the southward migration.

(4) In October the fish move further south, then migrate out of the region to sub-tropical and tropical waters (see Figure 16).

(5) Infrared imagery of a satellite is again extremely useful in detecting changes in oceanographic conditions and predicting the movement of fish schools.

5.3.8 Japanese flying squid

Japanese flying squid are abundantly distributed and caught intensively along both the Pacific and Japan Sea coasts of Japan (see section 4.8 and Figure 17). The forecast has therefore been carried out for both regions. However, the case employed in the Japan Sea is a typical example.

(1) Long-term forecasting

(1) Elements of forecast

Fishing ground, duration of fishing season, exploitable stock size by spawning group (autumn, winter and summer groups), total catch by spawning group.

(2) Frequency and timing

Regularly, twice a year, at the beginning and mid-point of the fishing season, June and August (the season usually ends in November).

(3) Cooperative abundance survey

Because of the importance of squid fishing in the region the cooperative survey has been carried out every year by a national institute responsible for the region and the local fisheries experimental stations on the coast. The survey is specifically designed to forecast squid fishing for the next fishing season. It has therefore been carried out just prior to, and at the beginning of, the fishing season. The survey aims first at ascertaining the abundance and distribution pattern of squid in the region, and second at collecting all relevant information, including oceanographic conditions. Observation by various methods is carried out simultaneously by a number of research vessels from local institutes which includes experimental fishing covering a wide area of the Sea. Figure 27 shows the cruise courses employed in such cooperative surveys.

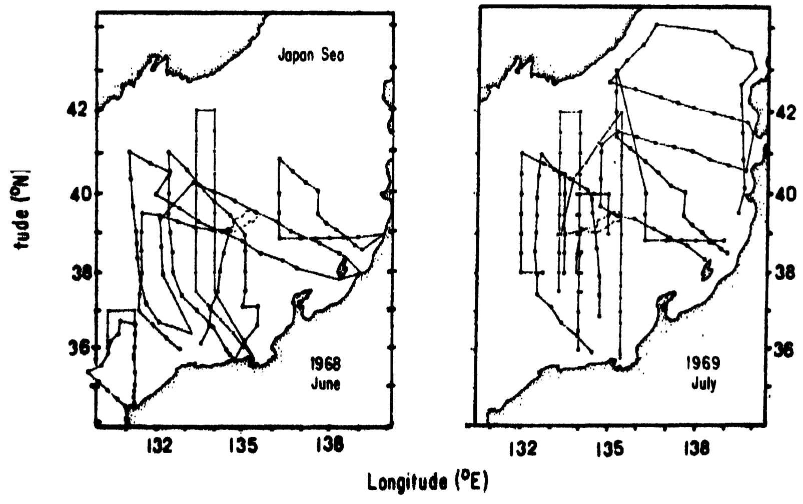

Figure 27 Cruise routes followed in the cooperative survey on pre-season abundance of Japanese flying squid in the Japan Sea (Kasahara and Ito, 1972). The survey has been carried out every year by several research vessels from local insti-

(4) Basic knowledge required

(a) The magnitude of the recruitment of a spawning group equals the relative abundance of the entire stock of the group as Japanese flying squid only live for one year, ending their lifespan after the first spawning at around age-1 (see section 4.8, (5)).

(b) In the Japan Sea the autumn group (spawned in autumn of the previous year) accounts for the largest portion of the exploitable stock although the winter group is larger in overall biomass when all Japanese waters are considered, including the Pacific Ocean (see section 4.8 (2) and Figure 17).

(c) The amount of the catch taken from offshore waters correlates generally well with the abundance of larvae observed during autumn of the previous year.

(d) The abundance of the stock and the distribution pattern ascertained by the cooperative survey mentioned above correlate fairly well with the catch rates (amount and its geographic distribution) for the entire fishing season.

(e) Most of the productive fishing grounds are usually formed along the water front at 50 m deep layer, where a sharp inclination of water temperature is formed. Figure 28 shows a clear example of this phenomenon, observed in September 1969.

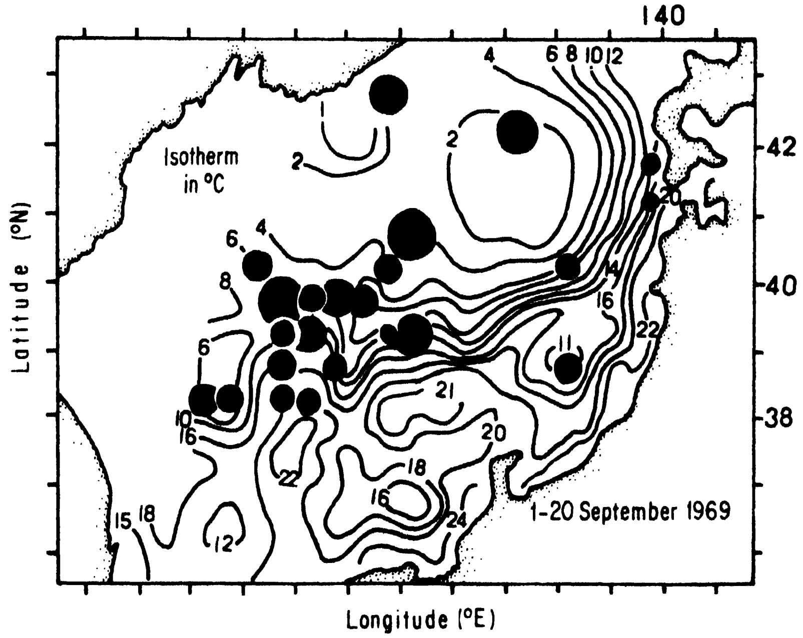

Figure 28 Relationship between the isotherms at 50 m depth layer and the distribution of Japanese flying squid in the Japan Sea (Kasahara and Ito, 1972). The size of solid circles indicates the magnitude of relative abundance of squid.

(f) Recruitment into coastal waters from offshore is usually high in a year when the offshore water front in the region meanders, while it is low when the front is parallel to the Japanese coast.

(g) Similar information on the other two spawning groups, winter and summer, is also taken into account.

(4) Forecast made for the fishing season, July to September 1982 (released in July 1982)

(i) The abundance of the autumn spawning group in 1982 will be at nearly the same level as that in 1981, and will therefore be substantially lower than in 1980.

(ii) The abundance of the winter and summer spawning groups will be slightly higher than the previous year. However, this will not contribute greatly to the total catch to be taken in the region as these groups generally account for a minor portion of the entire catch.

(iii) The total catch taken from the offshore zone of the Sea will be almost the same as that of last year.

(iv) The total amount of the catch taken in Japanese coastal waters will be nearly the same as that of the previous year, but the catch will differ locally, i.e. it will be higher along the western coast and lower along the east.

(v) The catch along the west coast of the Hokkaido, the northernmost fringe of the fishing ground in the Sea, will be slightly higher than last year as the fishing in the region depends mostly on the winter spawning group, for which higher abundance has been estimated for this fishing season.

(2) Short-term forecasting

Other than those mentioned above, no special data or information is required for short-term forecasting in the Japan Sea. This is because the basic knowledge acquired and the routine framework employed for long-term forecasting also fit fairly well the requirements for forecasting squid on a short-term basis.

However, two elements need to be highlighted. These are (1) the information on the water temperature gradient at around 50 m is extremely important to locate productive fishing grounds (see section 5.3.8 (1)-(4)-(d) and Figure 28) and (2) the location and pattern of the offshore water front (straight or meandering) is the second important factor in determining the aggregation pattern of squid schools (see the same section 5.3.8 (1)-(4)-(e) and Figure 28).

The infra-red imagery of a satellite is extremely useful for the latter purpose while locating the sharp gradient in a deep water layer needs to be done by a specially designed survey such as the cooperative research mentioned previously.

6. RELIABILITY AND SOUNDNESS OF FORECASTING

Needless to say, the prediction with higher reliability is more welcomed by users. In other words, the value of forecasting to the users depends greatly on the magnitude of the reduction of uncertainty for their future operations. Yamanaka (1975, 1976) discussed this from a theoretical point of view, applying an information theory to the relationship between Japanese tuna fishing and oceanographic conditions in the Indian and Pacific Oceans. However, it should be noted here that the reliability referred to in fisheries forecasting, especially that for fishing conditions, differs greatly from the concept employed in weather forecasts. That is, several man-made uncertainties and disagreements are inevitably involved in the process of formulating a prediction that fits natural conditions in the sea. For instance, the success or failure of fishing operations themselves (searching, locating and hauling etc.) partly determines the apparent accuracy of the prediction regardless of the correctness (in terms of logic) of the forecast made. Bearing this in mind, the authors present here a few examples of the accuracy achieved in the past.

6.1 Oceanographic Conditions

This is elementarily important as success in forecasting fishing conditions depends greatly on the accuracy of forecasting oceanographic conditions. The concept of accuracy here accords fairly well, although not completely, with that applied to weather forecasts.

(1) Long-term forecasting

The accuracy of forecasts made so far is fairly high overall. This is mostly a result of the long-term accumulation of information on oceanographic conditions which covers wide waters around Japan (see section 5.1). The intensive data collection currently employed has also played an important role in the overall success of this kind of forecasting (see sections 2.2, 2.4.3, Figures 1, 3 and 27).

However, there have been discrepancy when an unforeseen and sudden change in oceanographic parameters happened. This is one of the main difficulties to be overcome in the future, improving technological efficiency first to detect such changes as soon as possible and secondly to predict quickly their probable influence on oceanographic conditions.

An example of an assessment of long-term forecasting of the meandering pattern of the Kuroshio during 1978 to 1986 is given in Table 5, in which fairly good accuracy over the period is shown.

(2) Short-term forecasting

The short-term forecasts have gained very high scores for accuracy. This is natural, because (i) changes in current conditions are generally slight within a short time period and (ii) plentiful

Table 5

An assessment of the forecasting meandering pattern of the Kuroshio along the Pacific coast of Japan during 1978 to 1986. The forecast was made three times a year, March, July and November/December (see section 5.1.3, item (2) and Figure 19)

Year	Month	Forecast made[1]	Soundness
1978	Jul.	Type-1 dominates	Good, entirely
	Nov.	Continuation of above.	Good, entirely
1979	Mar.	Type-1 dominates	Good, entirely
	Jul.	Continuation of above	Good, entirely
	Nov.	Same as above.	Good, entirely
1980	Mar.	Type-1, with some variation	Good, fairly
	Jul.	Meandering gradually disappears.	Good, fairly
	Dec.	Type-II and/or Type-III appears for at least two to three months.	Good, entirely
1981	Mar.	Meandering first approaches coast, then leaves.	Good, fairly
	Jul.	Meandering shift its type from III to IV first, then disappears once and followed by Type-II.	Good, entirely
	Dec.	Type-II and -III appear alternately, or only Type-III remains.	Good, entirely
1982	Mar.	Type-II and -III recur during the period but the former dominates.	Good, fairly
	Jul.	Type-II and -III recur with nearly the same dominancy.	Good, entirely
	Dec.	Continuation of above.	Good, entirely
1983	Mar.	Continuation of above.	Good, fairly
	Jul.	Both Type-II and -III, or either one.	Good, fairly
	Dec.	Same as above.	Good, entirely
1984	Mar.	Type-II dominates.	Good, entirely
	Jul.	Type-II and -III recur first, then meandering disappears.	Good, fairly
	Dec.	Type-II is formed in February, then transformed into Type-III in April.	Good, fairly
1985	Mar.	Type-III first, transformed into -II, then meandering disappears.	Good, fairly
	Jul.	Type-III is formed in August but soon disappears.	Good, fairly
	Dec.	Type-III appears again but meandering soon disappears.	Good, fairly
1986	Mar.	Type-II appears first, transformed into -III but soon into II again.	Good, entirely
	Jul.	Meandering is not formed over the period.	Good, fairly

[1] See Figure 19 for the definition of meandering type

information is provided by fishing vessels once intensive fishing starts in the fishing grounds for which forecasts have been made. On average, 60 to 70 percent of forecasts have been entire accord, 20 to 30 percent fairly well, and 10 to 20 percent not in accordance.

In this category quick data handling and processing, including the dissemination of the results to ensure the timeliness of the forecasts is more important than upgrading the accuracy. This has greatly improved since the JFIC (Japan Fisheries Information Service Center) installed (i) quick communication systems such as radio and facsimile, (ii) computerized processing systems and (iii) a system for satellite imagery analysis routine (see section 2.5 and Figure 1).

Another factor to be noted here is the importance of meteorological information in short-term forecasting. Sudden and unforeseen changes in oceanographic conditions are sometimes caused by sudden changes in weather conditions, e.g. air temperature, wind force and direction, etc. These have been the major causes of failure in short-term forecasting, 10 to 20 percent on average, as mentioned above. Future improvement in this regard is required, similar to that of long-term forecasting (see section 6.1, item (1)).

6.2 Fishing Conditions

(1) Long-term forecasting

Evaluation of forecasts of long-term fishing conditions is rather difficult to make owing to the numerous and variform cases involved. Accuracy has therefore varied according to different factors, e.g. species, the status of the stock in question, localities and success or failure of fishing operations, etc. The authors present here three different examples of the accuracy of long-term forecasting highlighting special features involved in each.

(a) Japanese sardine

Table 6 shows fairly good scores as a whole. However, a species-specific feature is also clearly shown, which is the inaccuracy of the prediction of total catch. Markedly large underestimates were made in 1977 (260 000 vs. 460 000 tons), 1981 (550 000 vs. 710 000 tons), 1982 (600 000 vs. 810 000 tons) and 1983 (810 000 vs. 1 010 000 tons). The stock abundance of sardine increased rapidly during the above mentioned period for some natural reasons (see section 4.1, item (9)). This was the main reason why forecasts of total catch from the stock in the region were a failure. It is generally difficult to predict precisely the future trend of the availability of a fish when the stock is drastically changing its abundance. The prediction tends to be an underestimate when the stock is growing and an overestimate when the stock is declining. The former was the cause of failure in this case. An example of the reverse phenomenon will be given later (see the subsection on Japanese flying squid).

(b) Pacific saury

The accuracy of the forecasts made for the Northwest Pacific stock of saury along the northeast Pacific coast of Japan during 1976 to 1985 is summarized below. The forecasts are made usually twice a year, at the beginning and mid-point of the fishing season in the region, in August and October.

(i) Fishing ground

The major fishing grounds of fish schools migrating north along the coast are generally formed along the water front where the water temperature is around 10°C. The forecasts for this group have been fairly good as it is generally not so difficult to locate the water front.

Forecasting the location of offshore fishing grounds is also not difficult in a normal year, when clear and stable oceanographic conditions prevail. However, when considerable diversification occurs in oceanographic conditions, especially around the offshore Oyashio extension, the aggregation pattern of saury is greatly disturbed, resulting sometimes in failure to forecast offshore fishing grounds.

In short, forecasting fishing grounds of saury depends very much on oceanographic conditions in the area to which fish are migrating. Therefore, the forecast tends to fail when disturbance, which is unstable and difficult to predict, takes place. However, if such an anomaly in environment is predictable well in advance, a forecast can be made taking this into account. For instance, the sudden disappearance of fishing grounds was forecast in 1979 and 1984, when unfavourable oceanographic conditions were assumed several months before in an offshore zone in the former year and in a coastal zone in the latter. These were correct forecasts which, although discouraging for fishermen, prevented them wasting time and fuel in searching for target schools in vain.

Table 6

Evaluation of the long-term forecast made for Japanese sardine along the southeast coast of the Hokkaido during 1977 to 1985. The forecasting has been made in July every year, which is the beginning of the fishing season in the region. The fishing usually ends in October

Year	Forecast made: G: Fishing ground A: Age structure C: Total catch	Soundness
1977	G: Coastal zone.	Good, entirely
	A: Mixture of age-2 and -3 at beginning, but -1 (born previous year) join later.	Good, fairly, age-1 was more abundant than expected.
	C: 260 000 tons at most.	Bad, underestimated, 460 000 tons actual catch.
1978	G: Coastal zone	Good, entirely
	A: Mostly age-2 and -1.	Good, fairly, age-1 dominated.
	C: 460 000 tons at least.	Good, fairly, 440 000 tons actual catch.
1979	G: Coastal zone.	Good, entirely
	A: Mostly age-2 and -3 with small amount of age-1	Good, entirely
	C: 440 000 tons at least	Good, fairly, 550 000 tons actual catch
1980	G: Coastal zone, approach towards coast and stable there.	Good, entirely
	A: Mostly age-2 and -3 first, age-1 recruited later.	Good, fairly, very few age-1.
	C: 600 000 tons	Good, fairly, 550 000 tons actual catch
1981	G: Schools sparse in early season but dense later.	Good, entirely
	A: Mostly age-2 and partly -1 in early season but mostly age-1 later.	Good, fairly, age-1 dominated entirely.
	C: 550 000 tons at most.	Bad, underestimated, 710 000 tons actual catch.
1982	G: Coastal zone, move southwestward later.	Good, entirely
	A: Chiefly age-4 in early season age-2 recruited later.	Good, fairly, more age-2 fish.
	C: 600 000 tons	Bad, underestimated, 810 000 tons actual catch
1983	G: Offshore zone in early season, then enter coastal zone.	Good, fairly
	A: Mostly age-3 with older fish in early season, then chiefly age-3 and -2.	Good, fairly, very few fish older than -4
	C: Large but 810 000 tons at most.	Bad, underestimated, 1 010 000 tons actual catch.
1984	G: Coastal zone	Good, entirely
	A: Mostly age-4 in early season, age-3 and -2 middle, then age-1 later.	Good, fairly, less age-4 at beginning and less age-1 later.
	C: Large catch, greater than previous year (1 010 tons).	Good, entirely, 1 170 000 tons actual catch.

Table 6 (cont'd)

Year	Forecast made: G: Fishing ground A: Age structure C: Total catch	Soundness
1985	G: Coastal zone.	Good, entirely
	A: Mostly age-3 and -4 in early season, then age-1 and -2.	Good fairly, more older fish.
	C: Greater than previous year, (1 170 000 tons).	Bad, overestimated, 1 000 000 tons actual catch

(ii) Fish size

This is the most difficult area to get good marks in forecasting saury. For instance, only 40 percent success was achieved during the ten years of the above mentioned period. The causes are still unclear, and the subject needs further study. However, it is likely that the schools of different fish size may behave in slightly different ways, both in general and in reacting to specific environmental changes (see section 5.3.6, item (2)-2)).

(iii) Total catch

This is another difficult element to predict as it is subject to large annual fluctuations (see section 4.6 and Table 4). The forecast has, therefore, been made using as a basis the average catch taken over the past 11 years (an adjustment of plus/minus 10 percent of the average is then usually made). Various pieces of information collected until the time of forecasting (e.g. results of experimental pre-season fishing, etc.) are then taken into account when a decision on the final estimate is made.

Using this method, only one forecast, made in 1978, did not accord greatly with actual results during the ten year evaluation period. An unexpectedly large catch of 360 000 tons (Table 4) was taken against the prediction of 211-259 000 tons.

(c) Japanese flying squid

The authors present here a unique example in which very low accuracy was achieved. It is the result of the squid forecast made mostly for the winter spawning group which migrated into offshore waters along the northeastern coast of the Honshu during 1976 to 1986.

As mentioned previously (see section 4.8, item (9) and Table 4), the abundance of the winter spawning group has drastically declined since around 1975, on which squid fishing in the region had mostly depended. A clear explanation of the decline has not yet been given. However, it is likely that natural factors have been the major cause rather than fishing.

Because of the decline in the major exploitable stock in the region, fishermen began to shift their target species to a few oceanic squids, which have not been utilized before[1], extending the fishing ground into waters further offshore. The total catch of these squids in the region has exceeded that of Japanese flying squid from all the spawning groups in the entire Japanese waters since 1977 (cf. 184 000 vs. 133 000 tons in 1985).

[1] Neon flying squid, boreal clubhook squid and boreopacific gonate squid in the waters along the Kuril Islands and further east. Fisheries forecasting has not yet been applied to these species.

This situation has made the forecasting of flying squid in this particular region very difficult. First, decline in stock abundance for unknown reasons made it extremely difficult to predict the future trend of availability (this is a complete reverse of the phenomenon employed for Japanese sardine during the same period). Second, sparse distribution of squid schools also made it difficult to predict good fishing grounds in the region. Third, little fishing operation provides less information for forecasting purposes and fourth, the drastic change in species preference of fishermen may have masked the "correctness" of the forecasts made (e.g. no fishing attempted even if there were squids distributed as forecast, etc.).

Bearing all this in mind, the authors present here an assessment of the accuracy of the forecasts made for total catch of the winter spawning group in the region. Table 7 shows clearly the difficulties involved in forecasting fishing conditions in such a situation: only three predictions accorded with actual catch during the 11 year evaluation period.

Table 7

Comparison of the catches, forecasted and actually taken, of Japanese flying squid mostly the winter spawning group which have migrated into the offshore waters along the northeast coast of the Honshu during 1976 to 1986. Although forecasting was made twice a year, July and October, the two forecasts made in a year have been consolidated into one in the Table below for easy comparison

Year	Forecast made	Soundness
1976	First 38-48 000 tons, later amended to be substantially lower than above.	Bad, overestimated, 10 536 tons actual catch.
1977	Equivalent to last year, (10-11 000 tons).	Bad, overestimated, 7 269 tons actual catch.
1978	Equivalent to last year, (7-7 300 tons).	Bad, overestimated, 6 054 tons actual catch.
1979	In a range in recent years, (7-10 000 tons).	Bad, overestimated, 4 400 tons actual catch.
1980	Very poor catch.	Good, fairly, 2 026 tons actual catch.
1981	Recovering, (4-10 000 tons).	Good, fairly, 9 965 tons actual catch.
1982	At most 9 000 tons, likely, 4-6 000 tons.	Bad, overestimated, 3 288 tons actual catch.
1983	In a range in recent years, (2-9 000 tons).	Bad, overestimated, 1 796 tons actual catch.
1984	Equivalent to last year, (1 800 tons).	Good, fairly, 2 062 tons actual catch.
1985	At most 4 000 tons, at least 2 000 tons.	(Bad), no substantial catch, fishing not substantially performed[1/].
1986	Lowest in recent years (around 2 000 tons).	(Bad), same as above[1/].

[1/] Fishermen have almost completely changed their operation for fishing oceanic squids in further offshore waters, see text for details.

(2) Short-term forecasting

Similarly to oceanographic conditions, short-term forecasting of fishing conditions has generally been fairly accurate as more information is available on a real-time basis once fishing for the target species starts in the forecasted waters. This facilitates prediction of slight changes in fishing conditions in the immediate future. However, in some particular situations, like the winter spawning group of Japanese flying squid in recent years, accuracy has not been good, as examined above.

A survey by questionnaire was carried out by the JFIC (Japan Fisheries Information Service Center) to evaluate the short-term forecasts made for various species and localities in 1982. The results of the survey give some indication of the overall accuracy of short-term forecasts covering a number of variform cases. Among the 154 members of the JFIC who returned the questionnaire, about 4 percent judged that short-term forecasting in 1982 had been entirely accurate, 69 percent fairly accurate and 27 percent did not respond to this particular item in the questionnaire. This is encouraging, showing that about 70 percent of members, who are direct users of fisheries forecasting in various sectors, perceived that the forecasts had generally fitted actual fishing conditions well.

7. DISCUSSION

7.1 Usefulness

There is little doubt about the usefulness of fisheries forecasting employed in Japan since the majority of forecasts made so far have fitted actual fishing results fairly well, as was examined in the preceding section of this paper. However, when the usefulness of fisheries forecasting is examined, it should be borne in mind that the benefits are widely distributed to various people and entrepreneurs beyond fishing industries, which include fisheries administrators, brokers, dealers, retailers, processors, transporters, suppliers of gears, fuel and ice etc., investors and even consumers. Moreover, the majority of Japanese consumers do not complain about government expenditure on the forecasting service but rather welcome it as a means to assure consumers with stable supplies and prices of seafood for their daily consumption. In other words, fisheries forecasting in Japan has infiltrated deeply into the public domain.

Even when considering only fishing, fishermen must have encountered difficulties in taking a good catch if the prediction on fishing conditions was not available. This is because the target species of forecasting are all migratory and highly mobile pelagic fish, for which searching to locate fish schools is extremely important to fishing operations, with the exception of Japanese anchovy, for which short-term forecasting has not been applied.

The result of a survey by questionnaire carried out by the JFIC (Japan Fisheries Information Service Center) in 1982 shows a highly positive response from its members. Among 171 members who responded to the questionnaire, about 21 percent replied that forecasting had been quite useful, 74 percent useful and only 5 percent not useful. This may be expected, as the members of the JFIC are the direct users of forecasting, covering various fisheries associations, cooperatives, enterprises, wholesale markets and administrators in local governments bordering the sea, etc. All have the keenest interest in having the forecasts to facilitate their operations, planning and administration.

7.2 Costs and Benefits

7.2.1 Economic assessment

Although the utility of fisheries forecasting has been ascertained as discussed above, it is not possible to make a quantitative evaluation of its usefulness within the framework of this paper. There are two critical reasons: (1) none of the benefits brought about by fisheries forecasting can easily be quantified and (2) most of the expenditure on forecasting cannot be separated from the public domain.

The gains in economic profit to various beneficiaries are extremely difficult to estimate. Even if the examination is limited to fishing operations, the amount of profit on account of the fisheries forecasting is very difficult to calculate. This is because there is no substantial evidence immediately available to estimate the gains (e.g. capital cost saved, amount of catch increased, time and fuel saved, etc.) in comparison with the operations without forecasts. These can theoretically be figured out, however, various studies are required to be carefully carried out by well experienced economists, and a number of assumptions and estimates on economic parameters need to be employed even in these cases. These are beyond the scope of this paper.

It is more difficult to measure the benefits in sectors other than fishing. Namely, the economic gains to various commercial businesses brought about by the information provided by fisheries forecasting is almost impossible to assess directly within the framework of this paper. For instance, although there is no doubt that greater fluctuations would have accompanied the market prices of landings of target species if no forecast on probable catch were made available, the economic gain resulting from such a function is impossible to measure directly. The stabilization of market prices has certainly benefitted various people, e.g. in facilitating more stable prices for fishermen during the season, preventing over capitalization by processors, and in ensuring stable retail prices for consumers, etc. Although such an economic assessment could theoretically be made, the examinations required fall beyond the scope of this paper, as in the case of fishing operations, mentioned above.

Regarding the cost, it is impossible to calculate the total amount expended specifically on fisheries forecasting, because a large part of forecasting activities is inseparable from the regular programmes of the institutes concerned of both the central and local governments, as was discussed in an earlier part of this paper (see section 2.3 and Table 2).

The subsidy to the JFIC (Japan Fisheries Information Center) from the central government is the only expenditure entirely for fisheries forecasting (90 million yen or about US$ 700 000 per year). The JFIC runs on both the subsidy mentioned above and its own income (membership fees and earnings from selling reports and publication, about 50 million yen or about US$ 400 000 per year), totalling about 140 million yen or US$ 1.3 million (see section 2.3 and Table 2). Provision has been made for the JFIC's own income to increase substantially in the future. However, even on the assumption that the JFIC is entirely self-sufficient, the cost of a substantial part of forecasting activities, especially for survey and research, needs to be borne by both the central and local governments.

In other words, Japanese-type fisheries forecasting is not organized as a profit making operation. The system in Japan has thus settled down as one of the social investments for the whole society, although the prime beneficiaries are still the fishermen.

7.2.2 Fisheries forecasting and the national accounts

The authors present here a comparison with the national accounts to clarify further the highly public nature of fisheries forecasting in Japan. Nobody in Japan has attempted to examine the balance between the "cost and revenue" for the fisheries forecasting service. In this regard, the operational framework is very similar to that employed for the weather forecasting service. Namely, the limit of the cost (budget and activities) to be spent and the benefits (outcomes) to the public to be expected from fisheries forecasting have been politically and strictly defined by the central government within the framework and priority areas of national policy.

As is well known, Japan has traditionally depended greatly on fish as the major source of animal protein supply. Table 8 shows fisheries production and supply of major fishing countries of the world. The Japanese "catch", "food supply" and "per caput supply (consumption)" are all prominently high in comparison with other countries. USSR shows a fairly high catch and food supply but per caput supply is low at about 1/3 of that for Japan. In Iceland and Faeroe Is. per caput supply is high, but these are rather special cases with very low populations. These facts show clearly the importance of fish as food in Japan.

The total catch of the eight species for which fisheries forecasting has been employed (about 5.6 million tons, Tables 3 and 4) accounts for about 55-65 percent of the total marine catch. This is more than clear evidence of the importance of the fisheries forecasting service in Japan, first for food policy and second for industrial policy on the utilization of natural resources. For example, Japanese sardine is important not only for direct human consumption but also for the fish meal and aquaculture industries, rather like anchoveta in Peru, which is a world famous resource for fish meal.

Table 9 shows again the evidence of the importance of fisheries forecasting in Japan in terms of the value of fisheries production. The "total value of fishery production: Gross Fisheries Domestic Product (GFDP)" of Japan is prominently high compared with that of other member countries of OECD (Organization for Economic Cooperation and Development, Paris, France). This resulted in a fairly high ratio of the "GFDP" against the "Gross Domestic Product (GDP)" at 1.01 percent, which is the highest among these countries with the exception of Iceland. The ratio in Iceland is extremely large at 9.38 percent but the GFDP is very small at about 1/50 of that for Japan. It is interesting to note that a large differential exists in the level of GFDP/GDP between the six countries in the upper group and eight countries in the lower, which may have resulted from the difference in the level of dependency on fisheries production in each of the groups.

Table 8

Fisheries production and supply among major marine fishing countries

Country[1/]	Catch		Food[2/] supply	Population	Per caput supply
	Marine	Total			
	(000 t)		(000 t)	(000)	(kg/year)
Japan	11 156	11 368	8 887	119 239	74.5
Developed Countries					
USSR	9 274	10 102	7 410	272 549	27.2
USA	4 240	4 352	4 074	234 523	17.4
Norway	2 597	2 597	187	4 218	45.2
Denmark	1 855	1 879	112	5 115	22.0
Spain	1 272	1 297	1 253	37 910	33.1
Canada	1 272	1 323	511	24 902	20.5
Iceland	1 053	1 054	21	237	88.4
UK	825	870	1 002	56 604	17.7
France[3/]	753	753	1 340	54 715	24.5
Poland	656	687	637	36 571	17.4
South Africa	606	810	296	30 811	9.6
Netherlands	487	496	153	14 364	10.6
Italy	441	483	810	58 816	14.3
Faroe Is	299	301	4	42	97.9
Germany F Rep	292	315	572	61 412	9.3
Portugal	261	262	368	10 080	36.5
Sweden	259	270	244	8 330	29.3
German D Rep	214	232	239	16 696	14.3
Ireland	207	207	47	3 524	13.2
Developing Countries					
Chile	4 050	4 051	220	11 666	18.9
China	3 471	5 356	1 104	1 015 160	4.9
Peru	2 800	2 800	375	18 709	20.0
Korea Rep	2 338	2 386	1 774	39 978	44.1
Thailand	2 061	2 206	1 104	49 400	22.3
Indonesia	1 611	2 137	2 012	160 086	12.6
Korea D P Rep	1 508	1 600	762	19 410	39.3
India	1 574	2 578	2 272	730 173	3.1
Philippines	1 304	1 900	1 854	51 946	35.7
Mexico	1 086	1 163	741	75 109	9.9

[1/] (a) The countries with marine fish catch more than 200 000 tons in the Developed Countries and 1 000 000 tons in the Developing Countries. The grouping countries into "developed" and "developing" has been done based on the criterion defined by FAO.

(b) Source:

(1) FAO's Yearbook of Fishery Statistics, Catches and Landings, 1985
(2) FAO's Yearbook of Fishery Statistics, Fishery Commodities, 1985

[2/] Food Supply = (Total catch)-(reduction)+(Import)-(Export)+/-(Stock)

[3/] Production from inland waters was not available for the period examined

Table 9

Comparison of the Gross Fisheries Domestic Product (GFDP) with the Gross Domestic Product (GDP) in selected OECD Member Countries

Average 1983-84

Country	GFDP/GDP (%)	Total quantity 1/, 2/ of fishery product (000 t)	Total value 2/ of fishery product (GFDP) (US$ mill.)	Gross 3/ Domestic Product (GDP) (US$ mill.)	Per caput 3/ GDP (US$)
Japan	1.01	13 392	12 341	1 217 165	9 984
Iceland	9.38	1 108	239	2 547	10 616
Norway	0.90	2 598	502	55 284	13 268
Portugal 4/	0.89	293	176	19 869	1 975
Spain	0.72	1 134	1 124	155 644	4 147
Denmark	0.60	1 815	331	55 094	10 857
Ireland	0.33	206 5/	59 5/	17 830	5 105
Italy	0.20	431	693	352 769	6 179
Canada	0.20	1 295	668	333 969	13 211
Netherlands	0.18	408	230	128 839	8 834
France	0.13	689	644	503 211	9 171
UK	0.10	738 5/	385 5/	441 032	7 799
USA	0.10	4 403 5/	3 548 5/	3 537 904	14 662
Sweden	0.08	362	74	93 726	11 200

1/ (a) Source: OECD's Review of Fisheries, 1983, 1984 and 1985 (other than specified)

(b) OECD: Organization for Economic Cooperation and Development, Paris, France

(c) The values of the "gross value of fisheries product" were used for the GFDP since the data on the "gross fisheries domestic product", as defined strictly in economics, were available only for a few countries listed. The values of GFDP/GDP in the Table tend, therefore, to be slightly larger than those defined in economics.

2/ Total production from the entire fisheries, including fishing and aquaculture in both marine and fresh waters.

3/ Source: United Nations' National accounts statistics, 1985

4/ Only for 1983

5/ The total quantity of fisheries production has been adjusted by the FAO's statistics as the original figure was too small.

It should be noted, however, that the proportion of the fisheries product (GFDP) in the Gross Domestic Product (GDP) in Japan has been declining in recent years. Table 10 shows the annual change in the ratio of GFDP/GDP, which has decreased from about 1.3 to 1.5 percent in the early 1970s to about 0.9 percent in 1985. This has resulted from a greater increase in industrial production in the non-fisheries sectors. It is worth noting, in this regard, that the GFDP itself has greatly expanded during the same period, resulting in a twofold to threefold increase.

Table 11 shows the amount of the contributions in local currency of the fisheries and fish species, for which forecasting has been employed, to total fisheries production in Japan. The total amount of production by seven major coastal pelagic fish fisheries listed in the table, which are the most direct beneficiaries of the forecasting service, accounts for about 19.0 percent of the total fisheries production (GFDP) and about 25.1 percent of the total marine fisheries production (GMFDP).

Table 10

Annual change in the Gross Domestic Product (GDP) and
Gross Fisheries Domestic Product (GFDP) in Japan during 1970-85

Year	Gross[1] Domestic Product (GDP)	Gross[2] Fisheries Domestic Product (GFDP)	GFDP/GDP[2]
	(billion yen)		(%)
1970	73 345	996	1.36
1975	148 326	1 921	1.30
1976	166 573	2 208	1.33
1977	185 622	2 566	1.38
1978	204 405	2 464	1.21
1979	221 547	2 659	1.20
1980	240 177	2 784	1.16
1981	257 364	2 789	1.08
1982	269 626	2 972	1.10
1983	280 256	2 916	1.04
1984	297 948	2 947	0.99
1985	316 115	2 902	0.92

1/ Source: United Nations' National account statistics, 1985

2/ (a) Source: Japanese Yearbook of Fisheries Statistics. Fishing and Aquaculture, 1979 and 1985

(b) The values of the "gross value of fisheries output" were used instead of the "gross fisheries domestic product" defined in economics. The GFDP/GDP in the Table may, therefore, be slightly larger than those defined strictly in economics.

The total production of eight species[1] covered by the forecasting service accounts for about 15.6 percent of GFDP and about 20.6 percent of GMFDP. It is worth noting here that the total catch of these species in weight accounts usually for about 60 percent of the total marine catch (see third paragraph in this sub-section). This implies that fisheries forecasting for coastal pelagic fish has focused on supplying massive amounts of animal protein rather than pursuing high profits. However, even in terms of value, a 15 to 20 percent contribution to total production is quite substantial and indicates clearly the importance of fisheries forecasting in this regard too.

A comparison of the apparent budgetary basis (Table 2) with these figures may indicate the relative cost of the forecasting service. The total amount of the budget spent by the central government (1 614 million yen, including subsidies to local governments and JFIC) is about 0.29 percent of the value of total production of the seven major fisheries and about 0.35 percent of the total value of the eight fish species. The amount of subsidy to JFIC (90 million yen) is equivalent to about 0.016 percent of the former and about 0.020 percent of the latter. These figures are substantially small as a part of the cost of large-scale production. However, it should be stressed here again that fisheries forecasting can be carried out only when strong support by the regular programmes of both the national and local institutes is assured.

However, it is highly likely that the regular programme activities of the institutes of both the central and local governments will be strengthened rather than weakened in the future regardless of the continuation or discontinuation (the latter is highly unlikely) of the forecasting service.

1/ "Shirasu" is included mostly in anchovy and partly in sardine.

Table 11

Fisheries Domestic Product (FDP) for major fisheries and species for which fisheries forecasting has been employed in Japan[1]

Billion yen, average 1983-84

Fisheries		Species	FDP
Gross Fisheries Domestic Product (GFDP)			2 931.5
Gross Marine Fisheries Domestic Product (GMFDP)			2 218.5
Large/medium scale purse seine	172.4	Japanese sardine	90.7
Small scale purse seine	96.1	Japanese anchovy	18.8
Boat seine	69.8	"Shirasu"[3]	31.1
Saury stick-held dipnet	29.8	Japanese chub mackerel	76.6
Other dipnet	17.7	Japanese Jack mackerel	55.3
Skipjack pole and line[2]	41.6	Japanese amberjack	30.7
Squid jigging	128.4	Pacific saury	30.4
		Skipjack tuna[2]	24.8
		Japanese flying squid	99.6
Total	555.8		458.0

1/ (a) Source: Japanese Yearbook of Fisheries Statistics. Fishing and aquaculture, 1985

(b) See footnote to Table 10 for the definition of and a problem involved in GFDP, and

2/ Only for coastal and offshore waters around Japan

3/ Post larvae and fry of anchovy and sardine

7.3 Fisheries Forecasting and Management

In a broader sense, the fisheries forecasting service is one of the most important elements in the entire fisheries management in Japan. Its objectives and functions accord well not only with the philosophy of the "Fisheries Law", which defines the fundamental legal basis of fisheries in Japan, but also with global national policy and the economy as discussed in the previous two subsections.

In a narrower sense, however, there has been no tight linkage between the forecasting service and the management measures employed in Japan, especially in terms of controlling fishing mortalities of the target stocks through the regulation of catches. This is due firstly to the principles and structure of the fisheries management scheme employed in Japan, and secondly to the species-specific biological features of the target species forecasted.

For instance, the major function of short-term forecasting is to facilitate fishing operations for better catches by providing easier access to productive fishing grounds, and allowing more time to be spent fishing rather than searching. This results in increasing fishing mortality of the target stocks, but a negative consequence of fishing mortality is originally not included in fisheries forecasting.

Long-term forecasting has, on the other hand, sometimes been useful to the fisheries administrators, especially at the local level for the timely modification or adjustment of various regulatory measures currently employed. Even in these cases, however, the forecasts provide aid information only on a temporary basis. The basic management measures for long-term purposes have been established separately from the forecasting service, based on the various laws/acts and the results of resource appraisal made by the regular programmes of both the national and local institutes.

7.3.1 Management of relevant fisheries

One of the distinctive features of the fisheries management scheme in Japan, in contrast to those employed in other advanced fishing nations of the world, is that the catch quota system has scarcely been employed, especially for catching finfish. On very rare occasions, the catch quota system is applied to several local resources, e.g. red seaweeds, lobsters and abalone, etc., for which fisheries forecasting has not been employed. This is one of the basic reasons why the forecasted "total catch" does not imply the concept of "allowable catch".

In Japan, when the reduction or limitation of the total catch of specific fish species is needed for some reasons (e.g. conservation or economic purposes), regulation is achieved by controlling total fishing intensity of the fisheries concerned rather than limiting the total catch. It is usually done by either (1) reducing the number of operational vessels (abolishment or transfer of licences in the long term, and/or layoff of selected fishing vessels in the short term, e.g. skipjack tuna fishery) or (2) the adjustment of fishing season (establishment or extension of closure, e.g. Pacific saury fishery). The simplicity and effectiveness of these measures is far greater than those for controlling directly the total catch in Japan. In other words, the monitoring and surveillance of the "catch quota system" is practically impossible in Japan where numerous fishing vessels are currently operating (about 40 000 vessels for the major 8 fisheries listed in Table 12) and hundreds of landing places are scattered along the coast (there are 46 central and 734 local wholesale markets).

Table 12

Licensing and granting scheme of the major coastal pelagic fish fisheries around Japan

Fisheries (see Tables 3 and 11)	Licenser/grantor and conditions
Large/medium scale purse seine	Minister, licensed
Small scale purse seine	Governor, nationally registered
Boat seine	Governor, nationally registered
Saury stick-held dipnet	Minister, approved
Other dipnet	Governor, subject local regulations
Skipjack pole and line	Minister, licensed
Squid jigging	Minister, approved
Setnet	Governor, Fishing Right Fishery

Three major principles have been employed in the management scheme in Japan, i.e. (1) the enforcement of controls on total fishing intensity of respective fisheries in defined waters/areas limiting the number of gears and fishing vessels by their size category during the defined fishing season, (2) the establishment and enforcement of various conservation measures and (3) the implementation of coordination and cooperation among fishermen on their own by organizing and guiding fisheries cooperatives. The legal basis for these has been strictly defined by the three major fisheries laws, i.e. the (i) Fisheries Law, (ii) Fisheries Resources Conservation Law and (iii) Fisheries Cooperatives' Law. The details of the system and its functions have already been well documented in other papers, e.g. Asada, Hirasawa and Nagasaki, 1983, Chikuni, 1985. The authors, therefore, present here only a brief review focusing on the fisheries for which forecasting is employed.

(1) Limitation of total fishing intensity

The limitation of total fishing intensity has been enforced mostly through the licensing/granting scheme and partly by the implementation of various regulatory measures. As is shown in Table 12, there are 5 categories involved in the coastal pelagic fish fisheries; (i) Minister licensed, (ii) Minister approved, (iii) Governor licensed but nationally registered, (iv) Governor licensed but subject to local regulatory measures and (v) Governor licensed but defined by the Fisheries Law as one of the exclusive Fishing Right Fisheries.

In the first and second categories, the total amount of fishing intensity is decided by the Minister on a national basis. In the third category, the Governor issues licences within the total allowable amount in each of the prefectures allocated by the Minister. The Governor completely decides the limits in the fourth. In the fifth, the Governor grants the fishing rights but the details are strictly defined by the Fisheries Law.

The total allowable fishing intensity is generally defined by double limitations, i.e. (a) the total number of fishing vessels allowed by gross tonnage class within (b) the total amount of gross tonnage of all the vessels in the fishery in the specified waters.

(2) Conservation measures

The conservation measures to be employed by both the central and local governments are set out by the Fisheries Resources Conservation Law. The major orders defined by the law include the prohibition against and regulation of (i) catching, (ii) retaining and selling specific fish species, (iii) operating specific gears and vessels, (iv) discarding pollutants and (v) taking or displacing materials retained/deployed for conservation and propagation purposes. Under these principles, the law sets out further details of the conservation measures to be enforced for specific fisheries, resources and waters. These include the establishment of (a) conservation areas, (b) limitations on total fishing intensity, (c) closure of fishing ground and season, and (d) regulations on fish size to be caught/sold, etc.

(3) Coordination and cooperation of fishermen

All Japanese fishermen are organized into various types of fisheries cooperatives and are strongly encouraged, by various legal and incentive arrangements defined by the Fisheries Cooperatives' Law, to coordinate their fishing operations on their own to ensure efficient utilization of waters and resources. The law also requires mandatory cooperation between each of them and with fisheries administrations in carrying out enforcing various administrative tasks, including management and conservation measures.

The law originally aims at improving first the socio-economic status of fishermen and fisheries processors, second overall productivity in fisheries and ultimately the national economy. It therefore covers a very wide field of fisheries, especially for the economic benefit of members, e.g. (i) banking, credit, loan, (ii) supply and sale of gears, fuel, ice, food and other daily necessities, (iii) credit/mutual insurance and welfare, (iv) fishing by cooperatives, (v) transportation, wholesale, processing, storage and sale of catch and products, etc. However, activities for fisheries management have been actively performed together with these as an important part of the entire organization of fisheries cooperatives.

It is worth noting here that the majority of the cooperatives for coastal pelagic fish fisheries are members of the JFIC (Japan Fisheries Information Service Center), firstly as one of the most direct beneficiaries and secondly as one of the most cooperative counterparts. It should also be noted that the majority of fisheries radio stations along the Japanese coast have been organized and operated by fisheries cooperatives under the legal and incentive arrangements defined by the law (599 out of 729 radio stations along the coast in 1985). The fisheries radio stations are now one of the most important transmission network for fisheries forecasting for both the collection of data and the dissemination of forecasts, as was discussed previously. In this connection, the National Federation of Fisheries Radio Stations is one of the core members of the JFIC. It is also noted that a substantial number of fishing rights for setnet fishery (see Table 12) have been granted to fisheries cooperatives to ensure harmonious implementation of the exclusive-use-right of coastal zones (193 cooperatives own their setnet fishing right, which accounts for about 50 percent of fishing cooperatives[1] in 1985).

7.3.2 Biological features and management required

The annual catches of the eight species for which fisheries forecasting has been employed have shown large fluctuations over time, with the exception of Japanese anchovy (see section 4). This is a worldwide tendency observed in many of the neritic pelagic fish stocks (Csirke and Sharp, 1984, Csirke, 1988[2]). There is no doubt that these fluctuations have resulted from large changes in stock abundance in their respective species.

The causes of these phenomena are not yet clear. However, the consensus reached recently by the scientists concerned is that the main causes are natural and beyond human control. Regarding the coastal pelagic fish around Japan, no clear relationship has been observed, consistently in ny stocks[1], between fishing mortality and stock size. Therefore, there would be almost nothing to do with the "surplus-yield" type approach for the management of these stocks. The "yield-per-recruit" type approach may also be not entirely effective for management purposes for many coastal pelagic fish stocks around Japan, although the application of a model would, in some ways, be useful to examine a few biological features of the stock in question.

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[1] Cooperatives which operate some fishing on a self-supporting basis (384 in total in 1985). The total number of cooperatives along the entire coast, including those for both fishermen and fisheries processors, was 4 366 in 1985.

[2] Csirke, J., 1988, Small shoaling pelagic fish stocks. In Population dynamics, edited by J.A. Gulland. London, John Wiley and Sons (in press)

Probably no strict measures are required when the stock is growing since the stock abundance would increase exceeding the amount of reduction in total biomass, even if quite intensive fishing is attempted, as in the cases of Japanese sardine during the 1970's and Japanese chub mackerel during the 1960's. However, prudent regulatory measures are required when the stock is declining aiming firstly at assuring the reproductive potential at a certain level to enable the stock to increase again when favourable natural conditions arise during the declining period and, secondly, at avoiding a drastic and rapid deterioration in the fisheries (Asada, Hirasawa and Nagasaki, 1983, Chikuni, 1985, Csirke and Sharp, 1984).

The most important concerns for the management of these stocks are, therefore, first continuous monitoring (not only of recruitment size and total abundance but also overall status of the stock, including other biological features) and, second, limiting total fishing intensities when the stock shows a declining tendency. The fisheries forecasting service employed in Japan has contributed a great deal to these needs, especially in recent years, since the JFIC installed highly efficient infrastructure and equipment. For instance, reduction in fishing intensity for Japanese flying squid in recent years has been made by transferring the vessels to fishing for oceanic squids in further offshore waters (see section 6.2 item (c)) taking into account both the long- and short-term forecasts made. However, it should be stressed here again that the basic regulatory measures have been adjusted from time-to-time by both the central and local governments, apart from the forecasting, being based on the result of stock assessment made annually by the responsible institutes.

7.4 Requirements for Future Improvement

7.4.1 Scientific basis

As discussed in earlier parts of this paper, there are a number of problems involved in the scientific basis for fisheries forecasting, i.e. unknown causes of many phenomena, uncertainty and inaccuracy of various estimates and relationships between parameters and/or estimates, etc. The majority of these problems cannot be resolved within the framework of the forecasting service but must await improvements in the basic sciences through various studies in oceanography, marine biology, meteorology, etc. These tasks need to be carried out under the regular programmes of many scientific institutions, among which the national and local fisheries research institutes should play the most important role.

However, subjects that are highly forecasting oriented and a matter of urgency have to be studied within the forecasting project. The technology for detecting sudden changes in oceanographic parameters, the physical and biological effects of those changes, and the relationship between meteorological and oceanographic conditions are highlighted in this category. Various studies on fish behaviour, particularly related to sudden changes in environmental conditions, and to the various structures of oceanographic conditions, need to be carried out. This area is to be highlighted in the biological sector of this category.

7.4.2 Infrastructure and functions

Needless to say, increased efficiency of the system is better from a functional point of view. However, this should be decided by national policy, as discussed earlier (see section 7.2.2). As far as the basic system and its functions are concerned, no critical shortcomings are currently observed. Data collection and processing, and the dissemination of forecasts have been fairly satisfactorily carried out. However, steady and continuous upgrading and reinforcement of the quality of the forecasts should always be borne in mind in the future for the reasons mentioned below.

It has been observed recently that during the past 15 years the scientific and technical competence of Japanese fishermen has been greatly strengthened regarding understanding and utilization of oceanographic and fisheries forecasting. For instance, only a few fishermen could read the necessary information from an isotherm chart of the sea at the initial stage of the forecasting service (see Figures 4-A and 4-B), but now the majority of coastal fishermen can understand very well the oceanographic forecasts made with an isotherm chart, and many of them can even read a copy of satellite imagery (see Figures 5-A and 5-B). This implies that higher quality and quicker issue of the forecasts will be required in future in addition to improving the preciseness of forecasts.

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[1] e.g. Japanese sardine (see section 4.1), Japanese chub mackerel (section 4.3), Japanese Jack mackerel (section 4.4), Pacific saury (section 4.6) and Japanese flying squid (section 4.8).

The following items are specifically highlighted to meet this end:

(1) Further reinforcement of the collection of real-time data on fishing by selected cooperative fishing vessels;

(2) Quicker data processing, especially for the above;

(3) Utilization of multiple satellites, e.g. NOAA No. 9 and LANDSAT, USA, MOMO No. 1, Japan, etc., which would enable the service to upgrade accuracy and expand waters to be covered;

(4) Establishment of a systematic and easy-to-access "Data Base", which would facilitate greatly the various functions and relevant studies, especially the studies mentioned in sub-section 7.4.1, (about 80 million data per year are currently handled by the JFIC);

(5) Establishment of a computer communication system (e.g. MODEM system[1]) between JFIC and users who own a microcomputer (a trial has already started).

7.5 Applicability in General

Japan is one of the few countries in the world where fisheries forecasting is operational and covers a substantial number of fisheries and catches, and the desire to have such a system is now spreading to many people in many countries of the world where the fisheries forecasting service has not yet become available. This is one of the reasons why the authors have prepared this paper. The authors present here, in this regard, a brief but global review of applicability and general requirements to assist those people and countries to examine the feasibility of such a system.

7.5.1 Target species and environmental conditions

The examination of this aspect is especially important as the forecasting is made by projecting fish behaviour against the specific structure of the environment and/or its changes. To give an extreme example, if there is neither a specific structure in the environment (it is quite uniform) nor are there regular changes in it (it is extremely stable annually or seasonally), the behaviour of the target fish would mostly be at random. In such a case, the projection or estimate for the forecast would be no more than a guess, although this may be an extremely rare situation. There would not be random behaviour in the fish in any part of the world's oceans no matter how much the strength and magnitude of the correlations differ from case to case.

The important questions to be examined are, therefore, (1) how far the behaviour of the target fish correlates with the environment in the waters in question, (2) how much knowledge or data on such a relationship has been acquired so far and (3) what means are available and how much reliable data could be collected for monitoring purposes in the future. These also differ case by case and from one country to another, which results in various levels in the accuracy of forecasting. For instance, the accuracy of the forecasts made was not so high even in Japan at the initial stage of the service. In waters where the linkage between the environment and the behaviour of the target fish is originally rather weak, there may be no way to gain higher accuracy and reliability of forecasts even after the forecasting technique has been well developed. This would result in lower usefulness and smaller benefits owing to natural limiting factors beyond human control. For such cases a final decision needs to be taken by the government, weighing the "cost benefit" as discussed in the last subsection (section 7.5.3).

In any case, careful examinations of the target species and environmental conditions have to be firstly undertaken by the experts concerned before planning forecasting activities.

7.5.2 Linkage with fisheries management

If fisheries forecasting appears to be feasible, after the surveys mentioned above regardless of the level of its reliability and accuracy, a careful examination of how it is to be linked with the fisheries management currently employed in the country has to be carried out as the next step.

Needless to say, the existence and enforcement of adequate management measures in some way are indispensable for the introduction of fisheries forecasting, because the forecasts, if made, would certainly increase fishing mortality of the target species as discussed previously (see section

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[1] MODEM: Modular/Demodular, used for communication between computers.

7.3). If the forecasts to be given link closely to the substantial item(/s) of the management measures currently employed in the country, careful coordinating arrangements are required before ancement of the forecasting.

For example, assuming that the measures include a "catch quota" or "catch limit" system and that the forecast greatly improves the fishing efficiency of individual fishermen, several problems may arise if careful arrangements are not made beforehand *even when the stock is in a favourable condition*. For example, too much concentration (in both space and time) of fishing operations may cause wasteful landings within a very short period, or even a decline in individual catch rate and thus economic returns. The means and timing of the release of the forecasts may also need to be carefully chosen to prevent conflicts caused by inequity among the recipients.

Furthermore, if adequate measures and effective enforcement are not employed in controlling fishing mortality *when stock abundance is declining* for some reasons, fisheries forecasting, if made, would *accelerate* the deterioration of the stock and cause catastrophe in the fisheries, which is a result quite contrary to the original and to national objectives.

It should be noted here, in this connection, that the measures mentioned above would generally be extremely difficult to enforce if they took the form of single or isolated directives for a specific fish stock or fishery. It might be possible if the government possessed an extremely powerful police authority. However, this may be rare and may not be desirable. Instead, various coordinating arrangements, if made, would work rather more effectively and harmoniously than legal enforcement by a police force in many cases. These may include legal arrangements and incentives for transferring fishing from one fishery to another, a government or mutual compensation scheme for the permanent abolishment of licences or temporary laying-up of vessels, loan/credit or government subsidy for the interest on loans for these purposes, etc., all of which are options employed in Japan. In short, *comprehensive consideration* is required, especially when fishing activities need to be *constrained by the government*.

The problems and ways to resolve them differ greatly case by case according to management measures currently in force and the state of the fisheries in the country. Careful and *thorough* examinations are required, covering various aspects of the fisheries (e.g. legal, biological, economic and social, etc.) for which arrangements need to be made.

7.5.3 *Infrastructure, cost and benefit*

These are also quite variable by country. However, there may be no doubt, in all cases, that a substantial part of the activities will have to be undertaken by public institutions, especially research and study in the fields of both oceanography and marine biology. It is clear, therefore, that forecasting activities cannot all be put together as a profit making operation. Some activities, e.g. an information service like the JFIC's in Japan, can be made self-sufficient basis under some conditions.

However, it is highly unlikely that a large income for such an information service could easily be collected from the fishermen concerned. The majority of the target species are coastal pelagic fish, which usually fetch very low market prices, with the exception of skipjack tuna. Therefore, a large profit for fishermen, who would then be able to afford the expenditure for the information service, could be realized only when a large and stable catch from the target stocks is assured. The difficulty in collecting funds for the service or selling information on a commercial basis may be more serious in developing countries where both the "gross fisheries product" and "*per caput* fisheries product" are generally very low.

Besides, the equipment and facilities to be installed for efficient and prompt forecasting are generally quite expensive to acquire and to operate (e.g. those employed in the JFIC). This is one of the special features involved in fisheries forecasting for coastal pelagic fish, which inevitably tends to take on a "social welfare" role in this sector of the fishing industry.

As discussed previously, in Japan the entire project has been carried out by the government as a social investment. The authors do not intend to affirm that the Japanese system is ideal, but they would like to draw readers' attention specifically to the importance of taking fully into account the *socio-economic conditions* of both the fisheries in question and of the entire nation in the country. The Japanese case is a unique example where the social investment has not only had a great effect on the fisheries concerned but has also become a matter of public concern under the country's own conditions.

In conclusion, when planning the establishment of a fisheries forecasting system in a country, the government must examine carefully and make decisions on (1) feasibility in the natural environment, (2) structure, (3) costs and (4) benefits of the forecasting service. These have to be made according to (i) the availability of funds and resources (manpower, facilities and technical capabilities), (ii) the probable outcomes to be expected under both *natural* and *institutional* conditions, (iii) the status of the fisheries and the stocks in question from both an economic and managerial point of view, (iv) the socio-economic conditions and (v) the priority areas of national policy in the country.

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